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THESIS

AN EVALUATION OF THE EFFECT OF
SPARES ALLOWANCE POLICY UPON
SHIP AVAILABILITY AND RELIABILITY

by

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September 1980

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An Evaluation of the Effect of
Spares Allowance Policy Upon
Ship Availability and Reliability

by

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requirements for the degree of

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September 1980

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U.S. ships are provided onboard spare parts for equipment the ship's force is capable of repairing while at sea. The range and depth of spares provided has a pronounced effect on the availability of both ship and weapon systems. The spares suite for a particular ship is the Coordinated Shipboard Allowance List produced by the Ship's Parts Control Center. A mathematical model is used to produce this list, aiming to achieve stocking goals set by the Navy. This thesis examines the relationship between these goals and the model in use. A simulation model developed by the Naval Sea Systems Command has been modified so that it is compatible with the Naval Postgraduate School computer system, and this simulation model is used to evaluate the provisioning models. This simulation model is capable of being used for a variety of other projects at the Naval Postgraduate School.

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I. INTRODUCTION

The capability of a modern warship to be combat ready and maintain this readiness over a deployment period depends on logistics support. While this support includes such necessities as food, fuel, medical supplies etc., a crucial element in maintaining the sophisticated shipboard systems is the availability of repair parts. More important, of course, is the necessity of having a skilled technician capable of diagnosing any problems and effecting the required repairs. This thesis will focus entirely upon the 'part' side of this two-way problem, knowing full well that the desired technical expertise is not always available on all ships.

To provide for the capability of repairing equipment while away from port or support ships, each ship is provided a quantity of spares designed to enable it to be self sufficient for a period of 90 days. Budget and storage constraints prohibit stockpiling spares to cover all possible requirements, therefore a choice must be made as to the method to allocate the range and depth of spares to be provided.

Chapter II discusses the way the Navy is currently making this allocation. The method has been successful for a number of years, but less so recently due to changes in

provisioning model parameters. These changes were dictated by the 'high cost' of the allowance list generated by previous parameters.

Chapters III, IV, and V describe the use of a reliability block diagram simulation program to evaluate the effect of changing the spares suite upon the reliability/availability of a shipboard system over a 90 day period with no external spares replenishment. To obtain an upper bound on the spares effectiveness, the 90 day period was simulated with all repairs being instantaneous; thereby placing the entire burden of making the system available on the spares suite and not upon the speed of the repair. From this technique a measure of effectiveness of each given spares suite can be derived.

As an example, a particular reliability block diagram is analyzed in chapter VI using the simulation technique. The nature/configuration of this block diagram has a large effect on the figure of merit results. For example, three different items connected in series would be less reliable than the same three connected in parallel where only two are required to be functioning at once and the third was in cold standby. It is for this type of reason that a provisioning process based on parts counting rather than reliability may provide satisfactory results for one system and unsatisfactory results for another when both systems possibly consist of the same piece parts or perform the same function.

The simulation (called TIGER) is a general reliability simulation model and is capable of many other uses besides the one chosen for this thesis. With the help of the appendices, the program listing, and the TIGER manual (Ref. 1) further use of this program on the Naval Postgraduate School (NPS) computer system or any other FORTRAN IV compatible system with random number generation capability should be feasible.

II. THE COORDINATED SHIPBOARD ALLOWANCE LIST (COSAL)

A. NAVY POLICY FOR PROVIDING SUPPLY SUPPORT OF THE OPERATING FORCES

The amount of logistic support required to support the desired levels of fleet readiness are delineated in Ref. 2. Of concern here are the sections on Shipboard Stock Levels and Criteria for Shipboard Allowances.

All non-Fleet Ballistic Missile (FBM) self-sustaining ships have a stockage objective of 90 days, which is equated to the endurance for the ship. This objective is applicable to repair parts, spares, and equipment related consumables.

The specific criterion for developing a COSAL from a list of those items capable of being repaired by shipboard personnel is the subject of the next section of this thesis.

The measures of effectiveness for COSAL performance as stated in Ref. 2, are to 'fill from onboard stocks 65% (gross effectiveness) of all demands and to provide an overall availability for items allowed to be carried of 85% (net effectiveness)'. It is essential to note that no mention is made of such terms as reliability, availability, or readiness in the context of the supported ship as a measure of COSAL effectiveness.

Net effectiveness is often called 'system' effectiveness, in that it is the effectiveness of the entire logistics

system in replenishing shipboard spares once they are used and reordered. As this is not specifically related to the COSAL provisioning document, but is a function of such diverse items as order and shipping times, specific examination of this measure will not be attempted. Rather, certain stated assumptions will be made regarding the percentage of spares onboard when it is necessary to do so.

The objective of 65% gross effectiveness is the central issue which this thesis will focus upon. As will be shown in the next section, the COSAL mathematical model in no way can be substantiated as a '65% gross effectiveness model'. More important is the question of '65% gross effectiveness' as a measure of effectiveness for shipboard support. One could conceive of ways to fill 75% of the requisitions received in 90 days from shipboard stock and never be able to get underway. Alternatively, a low fill rate could result in a highly successful deployment. The key, obviously, is to stock those items which are important to the ships mission, and not to stock simply to maximize stock turn.

B. CURRENT COSAL MATHEMATICAL MODELS

Several mathematical models are currently being used to generate COSALs. The Fleet Logistic Support Improvement Program (FLSIP) model is used for surface ships and Fast Attack Submarines (SSN) and is the most extensively used technique. The TRIDENT model is used on Fleet Ballistic

Missile Submarines (FBM) and is similar to the Maintenance Criticality Oriented (MCO) COSAL being implemented on the FFG-7 Lo-Mix class of ships.

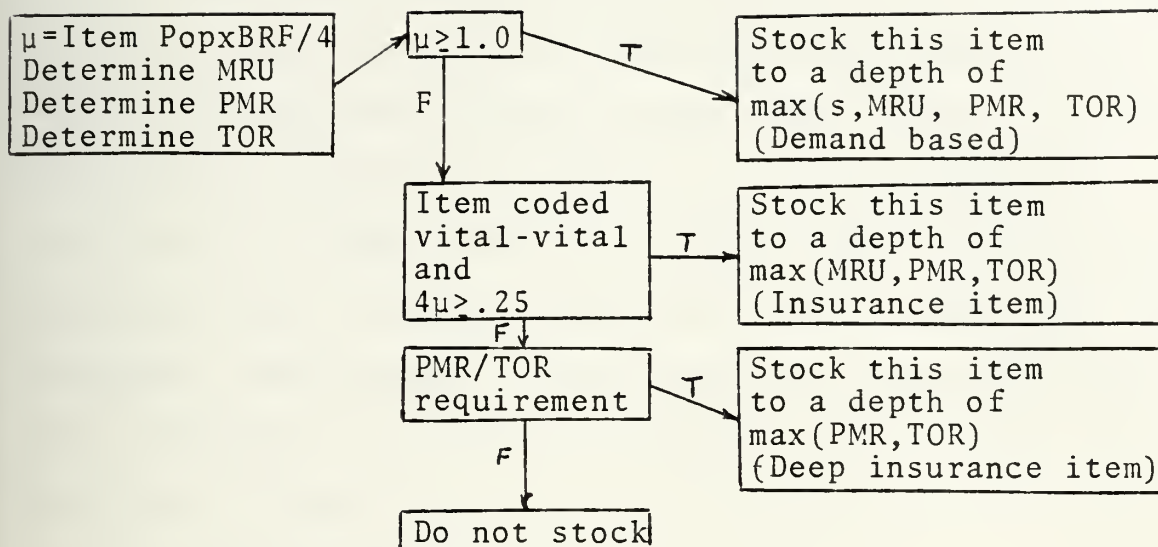
1. FLSIP Model

The FLSIP model has been in use for many years and has proven to be a rapid, workable, and understandable method of generating the large quantity of COSALS that must be run (approximately 50 per month). This model simply processes a list of all repair parts applicable to the particular ship and capable of being replaced by the ship's force. Each part is individually totaled for its' entire installed shipwide population and then is multiplied by its' Best Replacement Factor (BRF) (explained in chapter IV). The resultant value is called the 'mean', and this mean is used with the essentiality of the parent equipment to determine the final allowance quantity. A FLSIP logic diagram is shown in figure 1.

The attempt to incorporate essentiality into this model has been negated by the migration of over 90 percent of the parts on file into the 'vital' category. Technical Overrides (TORS) have been frozen by the Chief of Naval Operations (CNO) as a cost reduction measure.

The currently used model is called a .25 FLSIP model since the insurance cut point is .25 (one expected demand in four years). As over 90 percent of the items stocked on-board a ship are stocked at a depth of one, this cut point is critical to the ability of the model to provide sufficient

FLSIP COSAL LOGIC



Definitions:

Item Pop - Consolidated population of the item throughout the ship's systems

BRF - Best replacement factor

s - minimum stocking depth such that
Pr (Actual 90-day demand $\geq$ s) $\approx$.90
(Assuming Poisson distribution)

MRU - Minimum replacement 'unit'
quantity, if any

PMR - Required preventative maintenance
quantity for planned maintenance

TOR - Technical override quantity, if any;
determined by engineers/designers
during equipment provisioning review

Vital-Vital code - Item vital to its parent
component, and its component vital
to a primary mission

Figure 1

support. This cut point was changed from a previous value of .15 due to various budgetary pressures.

Aside from the arbitrary nature of the value chosen as the cut point the main problems which continue to exist are the effectiveness criteria established in Ref. 2 and the fact that the FLSIP model (Figure 1) has no mathematical relationship to these criteria. If the FLSIP is to be continued in use, and indications are that it will (Ref. 3), meaningful effectiveness criteria must be established and a means developed to justify the use of the FLSIP model to meet these criteria.

2. TRIDENT Model

The TRIDENT model incorporates military essentiality codes (MEC) assigned to the parent equipment into the stockage allowance decision. The more essential the equipment, the better it will be supported. The following equation is used to calculate the allowance quantity:

$$\text{Allowance quantity} = \mu + (Z \times \mu)$$

Where μ is the mean of the assumed Poisson distribution of repair part requirements in 90 days).

The multiplier Z is a function of essentiality and to a lesser degree the unit price of the part. As in the FLSIP model each candidate part is processed individually and is not subject to budget constraints (although the levels may be adjusted through the manipulation of the various factors which comprise Z).

This model is currently in use; takes essentiality of equipment into account; and provides excellent support. But as could be expected, the resulting COSAL provides generous allocation of spare parts and its cost would be hard to justify outside of the FBM arena.

3. Maintenance Criticality Oriented (MCO) Model

The MCO model is an allowance list to be implemented on an increment of the new FFG-7 Lo-Mix class of ships. The mathematical technique is very similar to the TRIDENT model, the main difference being that essentiality is carried all of the way to the part level. The documentation required to achieve this is extensive and costly and must be maintained throughout the life of the ship. The documentation required to backfit the MCO model to older classes of ships does not exist.

III. THE NAVAL SEA SYSTEMS COMMAND TIGER SIMULATION PROGRAM

A. INTRODUCTION

TIGER is the generic name for a family of computer simulation programs which can be used to evaluate a complex system in order to estimate various reliability, readiness, and availability measures. This program was developed by the Naval Sea Systems Command (NAVSEA) reliability branch. The reliability block diagram of the system/component under study is the foundation from which a TIGER simulation run is constructed. This block diagram may be for a large system (ship) with each block representing a component of the system; or it may be for a single component with each block representing a lowest replacement unit part; or the block diagram may be any type of combination of both. As an input for each block the Mean Time Between Failures (MTBF) and Mean Time to Repair (MTTR) must also be known.

The unique feature about TIGER is the flexibility incorporated into the program. Scenarios with block diagram configurations which change during the time period being simulated are evaluated through a series of different timeline 'phases' in the input. A phase is a specific reliability configuration for the ship being studied. The simulation will accept up to six different phases, and they may be sequenced in any order and be of any interval of time. The

phases may be strung together until the simulation capacity of 95 total phases is reached. MTBF, MTTR, and spares multiplier factors may be entered to perform sensitivity analyses on the system under study.

TIGER uses Monte Carlo random number methods to evaluate the input block diagram. The random numbers are generated through the use of the NPS LLRANDOM routine (Ref.4).

The TIGER simulation is a discrete event step simulation. Exponential failure and repair times are generated using the MTBF and MTTR input data. As equipments fail spares are used; repairs effected (if allowed in the phase); standby equipment turned on/off if required; and different block diagrams initiated as the different phases are encountered during the timeline. Statistics are collected as a result of each event and change of configuration.

The TIGER output includes estimates of reliability, readiness, availability, and critical components which caused the most severe degradation of reliability and availability. The user may change the random number seed and replicate a timeline as many as 1000 times in a single TIGER run. TIGER will calculate and provide a lower confidence limit for the point estimate of reliability.

The inherent limitations to the use of this type of simulation include both the problem of providing accurate input data (MTBF, MTTR) and the exponential failure/repair rate assumption used in the program. Under many scenarios and for many types of equipment this exponential assumption is valid

but certainly many types of equipment exhibit wearout and not all repair times are exponentially distributed.

In addition to the output mentioned above, spares usage may also be displayed as well as several standard and optional outputs of the progress of the simulation. The detail can vary from every event being shown to a much simpler management summary.

Two subroutines of TIGER were omitted in this thesis research but may be useful in different types of analysis. One of these, the GAMMA option, assumes that the system being evaluated has a gamma failure distribution and calculates the two parameters (shape and scale) for the gamma distribution which would exhibit the same mean and variance of mission failure times as the system being modeled. The DEMO option of TIGER provides the capability of generating a sequential probability test ratio plan for the system as prescribed in MIL-STD-781. Detailed information about TIGER including GAMMA; DEMO; and a TIGER/MANNING personnel requirements type program is found in Ref. 1.

B. PRESENT NAVSEA TIGER UTILIZATION

The TIGER program is being used by NAVSEA to evaluate Reliability, Maintainability, Availability (RMA) performance characteristics of new ship classes (Ref. 5). This analysis is performed only on the major mission-essential systems: Navigation, Auxiliary, Electrical, Ship Control, Propulsion,

Exterior Communications, and Combat. Only these systems and equipment which impact the operational readiness of the ship and the ship's ability to perform its assigned primary combatant mission are included in the analysis.

All surface ships constructed since 1970 have reliability block diagrams available (in computer readable form). This eliminates the major undertaking of having to construct the reliability block diagrams prior to using TIGER. The necessary MTBF and MTTR data for existing equipment is found in the Reliability/Maintainability/Availability Design Data Bank (Ref. 6), which is a compilation of data from both engineering design and fleet feedback. Engineering estimates must be used for the many new systems found on a new class of ship, where no feedback data yet exists.

Along with the various reliability block diagram configurations (steaming, in-port, ASW, etc.) and MTBF/MTTR data, the operating rules for the equipment must also be provided. These rules include allowable downtime, spares, mission timelines, and maintenance policy.

A sample RMA timeline (Ref. 5) is shown in figure 2. Timelines are tailored to the class of ship and its designed usage in a period of combat.

Allowable downtime is the time that the system or equipment can be down for maintenance without causing a mission abort. During simulated combat periods this time is usually zero for most mission essential systems.

Maintenance policy limits certain equipment to being capable of repair only during certain phases. For example, repair of the main engine would not be permitted while hunting a submarine, but would be permitted while in-port.

Spares are assumed to be available as needed for initial TIGER analysis. Supportability tradeoff studies are conducted separately to evaluate the effect of different spares efficiency percentages and off-ship logistic delay times.

The results of the TIGER simulation are compared with design specifications to see if any inherent (non-spares related) reliability problems exist. Critical equipments are then identified and closely monitored during the final phases of design and construction.

C. PROPOSED TIGER UTILIZATION FOR COSAL PREPARATION

Reference 7 describes a methodology of using the TIGER program to evaluate a COSAL with respect to reliability. The inputs to the TIGER program would be the same as those in the last section with the exception of the spares input and the indenture level of the reliability block diagram. The diagram must not stop at the equipment level, but be carried out to the repair part level. MTBF/MTTR data must also be provided at the repair part level.

As may be readily apparent, the block design for just the essential equipment of an entire ship would be very cumbersome and unworkable. This type of TIGER analysis must

be done on a system or equipment basis. The spares input would be that generated by the COSAL model under evaluation, usually FLSIP.

A deployment timeline is simulated and the resulting reliability/availability figures are compared to the design goals. If the goals are not achieved the 'bad apples' list of repair parts indicates the particular parts which caused the most degradation. Additional quantities of these parts are added to the spares suite and the process is repeated until the goal is attained. This method may also be used in reverse, removing spares and observing the resulting changes to reliability/availability.

While this methodology is feasible and would certainly provide better support than an unaugmented FLSIP COSAL, it has several drawbacks. One is the lack of reliability block diagrams down to the repair part level. Although new equipment procurement contracts may specify that this documentation must be provided, the task of assembling it for just one ship's essential equipment would be awesome.

Another problem is the lack of MTBF/MTTR data for each part. Reference 8 may be used to estimate the required parameters, but again this is a large undertaking. As was mentioned earlier in this thesis, current provisioning processes use a BRF vice MTBF to determine logistic support. A further clarification of the differences between these two and a proposed solution will follow in a later section.

A final problem results from the fact that repeated computer runs on a vast network of reliability block diagrams are required to produce a single COSAL. The computer system at the Ships Parts Control Center (SPCC) is saturated and could not begin to process the large quantity of simulation runs necessary to use this proposed method on all COSALs. In addition, a significant number of manhours would be required to review each run and decide which parts to augment and in what quantity. Though this process would undoubtedly produce a COSAL superior to the FSLIP model, practicality prevents its adaption at the present time.

IV. BEST REPLACEMENT FACTOR (BRF)

A. BRF - WHAT IS IT?

The BRF is the projected annual replacement rate for one installed unit of a repair part. Only one BRF exists for each part even if it is used in numerous applications throughout a given ship or the fleet or ashore. The BRF is found by dividing the annual reported usage in the fleet by the total installed population. This yields annual failures per installation. Before any calculations are made the input data are adjusted for inaccuracies caused by bad reporters and inactive ships in overhaul. The BRF is calculated annually for each item in the SPCC files. To prevent rapid fluctuations from occurring the previous value on file is updated with the new value by the use of exponential smoothing.

To illustrate this process suppose that 105 ships in the fleet were each recorded as having two of part 'A' installed. Five ships were in overhaul for this particular year so their data is not used for BRF update. The remaining 100 ships reported a total of 400 failures for item 'A'. Since there are 200 of 'A' installed and 400 were used, the unsmoothed BRF is $400/200 = 2.0$. If the BRF currently on file is 2.4 and exponential smoothing with smoothing constant .25 is used, the updated BRF would be $2.4 \times .75 + 2.0 \times .25 = 2.3$.

This BRF would be put on file for use in all COSALS which contain part 'A'.

B. MEAN TIME BETWEEN FAILURE (MTBF)

MTBF is the expected value of the operating time between failures of an item. It is estimated by dividing the total time in service by the number of failures:

$$\text{MTBF} = \text{total time in service} / \text{number of failures}$$

Sometimes the expression Mean Time to Failure (MTTF) is used for the expected value. Another related measure is the failure (hazard) rate which is the conditional probability that an item surviving to age t will fail in the interval $(t, t+dt)$. A constant failure rate is equivalent to having a failure distribution which is exponential; and for an exponential distribution the failure rate is the reciprocal of MTBF.

C. DIFFERENCES BETWEEN MTBF AND BRF

A MTBF provides an expected value of the length of time an item will operate until failure. It is based on operating time; and failures are not possible while the equipment is not in use or turned on. A BRF is the average number of times an item will fail in an average year in an average installation. Since these differences and similarities are crucial to the analysis in section VI of this thesis, the following example taken from Ref. 9 provides an insight into the MTBF/BRF relationship.

A piece of equipment (lamp) has four repair parts (bulb, socket/switch, cord, plug). It is operated for 1000 hours per year. An arbitrary MTBF and corresponding Failure Rate (expressed in failures per year) are shown below:

<u>ITEM</u>	<u>MTBF</u>	<u>FAILURE RATE</u>
Light Bulb	750 HRS	1.333
Socket/Switch	10,000 HRS	0.100
Electric Cord	15,000 HRS	0.066
Plug	10,000 HRS	0.100
TOTAL		1.599

As shown, the lamp is expected to fail 1.599 times per year. This would be a BRF for the lamp if the maintenance policy were to replace the whole lamp no matter what the cause of the failure. The following table shows how maintenance philosophy can have a pronounced effect on the five BRFs. The 'Replace Failed Part' column represents the way repairs are usually accomplished at the shipboard level. Only catastrophic failure would lead to the attempted replacement of the entire item, usually unsuccessful because the entire assembly would not likely be stocked due to the low BRF.

<u>ITEM</u>	<u>FAILURE RATE PER YEAR</u>	<u>MAINTENANCE PHILOSOPHY</u>		
		<u>REPLACE FAILED PART</u>	<u>REPLACE LAMP</u>	<u>REPLACE FAILED BULB, OTHERWISE REPLACE LAMP</u>
LAMP	1.599	BRF=0.	BRF=1.599	BRF= .266
BULB	1.333	BRF=1.333	BRF=0	BRF=1.333
CORD	0.066	BRF=0.066	BRF=0	BRF=0
S/SWITCH	0.100	BRF=0.100	BRF=0	BRF=0
PLUG	0.100	BRF=0.100	BRF=0	BRF=0

D. BRF AS AN INPUT TO TIGER

When MTBF is used as an input to TIGER, various timelines are used to provide scenarios in which the equipment configurations and usage rates are required. When equipment is on, it fails exponentially with the given MTBF, unless the duty cycle is less than 100 percent, in which case the MTBF is divided by the duty cycle. The BRF has incorporated the various reasons the timeline approach must be used with the MTBF; equipment being turned off and on; duty cycles for equipment with cycles of less than one; and the various configuration dependent usage rates for an average installation in an average year.

Consider, for example, an equipment with a duty cycle of one-half (operating 50 percent of the time) exhibiting five failures in a ten year period. The MTBF is calculated as before; total time in-service/failures = $(10 \times .5) / 5 = 1$ year. Since the duty cycle is one-half, we would expect to see a failure every other year, or .5 per year. The BRF calculation yields the same result; 5 failures/10 years = .5 failures/year.

To use a BRF in TIGER requires that the entire block diagram, in a typical configuration, be used and equipment/parts be allowed to fail at an annual rate (BRF) which takes the numerous operating scenarios into account. While the results from this type of analysis would be very difficult to defend as providing entirely accurate reliability/

availability measures; they should be suitable for deriving a 'figure of merit' evaluation for the support provided by different COSAL models.

V. TIGER USED TO EVALUATE THE EFFECT OF SPARES ALLOWANCE POLICY UPON RELIABILITY AND AVAILABILITY

A. INTRODUCTION

The current utilization of gross effectiveness as a measure of COSAL effectiveness has been studied in previous sections. An alternative measure will now be proposed. The TIGER program calculates reliability, availability, and readiness figures for each simulation run. The definitions for these three measures, as found in Ref. 1, are summarized below.

B. RELIABILITY (REL)

For a given timeline the reliability (REL), as estimated by TIGER, is the probability that the ship will successfully complete the entire timeline. For example, if the timeline previously shown in figure 2 were used, REL would be the probability of the ship completing all of the different missions assigned during the 60 day period, in the sequence shown.

Reliability is calculated by TIGER as follows:

$$\text{REL (EST)} = 1 - \frac{\text{Number of mission failures (aborts)}}{\text{Total number of simulated missions}}$$

Note that this calculation incorporates logistics support considerations.

C. AVAILABILITY (AVA)

TIGER calculates two AVA parameters: Instantaneous and average. Instantaneous availability is the probability that the system will be 'up' at a specific point in time. Average availability is the probability that the system will be up at a random point in time. Because of the way TIGER is used, average availability is the relevant measure.

Average AVA is estimated as the ratio of total system 'uptime' to the total time simulated. These times are totaled for the entire number of missions simulated (up to 1000). The calculation is made as follows:

$$\begin{aligned} \text{AVA (EST)} &= \frac{\text{Summation of uptime for all} \\ &\quad \text{missions simulated}}{\text{Summation of total mission calendar time} \\ &\quad \text{for all missions simulated}} \\ &= \frac{\text{Uptime}}{\text{Calendar time}} \end{aligned}$$

D. READINESS (RED)

RED, like AVA can be measured as instantaneous or average readiness. It is a measure of the probability that there is neither a mission abort nor a system down. The forthcoming methodology for the use of TIGER results in RED equaling AVA, so RED will not be considered any further as an alternative measure of effectiveness.

E. RELIABILITY VS AVAILABILITY AS A MEASURE OF EFFECTIVENESS

A very common measure of effectiveness in use by the Navy today is 'Operational Availability' (Ao). Ao is defined as the probability that an equipment is ready when you need it. MIL-HDBK-217C (Ref. 8) dictates that it be calculated by:

$$Ao = \frac{MTBF}{MTBF + MTTR}$$

An alternative form of this equation results from breaking the MTTR up into the repair time (MTTR) plus the Mean Supply Response Time (MSRT); the time necessary to provide the required repair part(s). This yields:

$$Ao = \frac{MTBF}{MTBF + MTTR + MSRT}$$

There are problems with the use of this formula for estimating system operational availability (Ref. 10). From a mathematical point of view the formula yields the correct result for the limiting value of operational availability when one considers a single component that transitions between up and down states as an alternating renewal process. If one is interested in the operational availability after a fixed period of time for a system whose components have limited spares support, the formula does not yield correct results. In fact, the formula makes little sense. A simulation like TIGER is precisely what is needed to estimate Ao for a complex system with limited spares support.

Since AVA implicitly considers component reliability, maintenance, spare parts support, system configuration and

operational scenario, it is used in this thesis to evaluate COSAL models.

F. ALLOWANCE POLICY EFFECT

1. Reliability Block Diagram of System

The effect of a parts-counting type allowance policy upon reliability/availability is dependent on the configuration of the system being supported. Parts counting is a method of allocating spares in proportion to the number of each specific repair part in the equipment. In an environment of limited budgets and storage space, a more 'critical' spare (in terms of reliability/availability) may be sacrificed to provide unwarranted depth for another spare.

Figure 3 shows a simple reliability block diagram with two

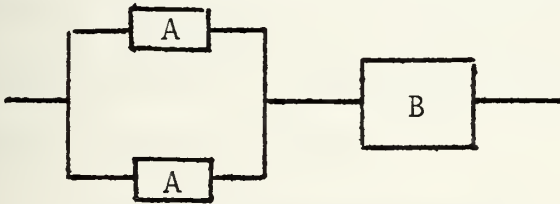


Figure 3

of part A in parallel with each other and then in series with part B. Both A and B have a BRF of 1. If A cost the same as B, and only one spare could be provided, provisioning by parts counting would provide one spare of type A, since there are twice as many A as B. However, the availability of this system would be much greater (all other things considered the same) if the one spare purchased were of type B, due to the parallel redundancy.

2. Proposed Allowance Policy Input

There are two methods of entering the quantity of spares for each part type into the TIGER simulation. One is to input that quantity as part of the input data. For small systems this may be the most efficient method. For larger systems or for those systems requiring a complicated mathematical model, a subroutine has been added to TIGER to calculate the COSAL.

For the FLSIP COSAL, the cut point is input with the other system data and the spares subroutine is used to generate the COSAL for the system. The MTBF is derived from the BRF in the following manner:

$$\text{MTBF} = (1/\text{BRF}) \times 8766 \text{ (yr/fail)} \times (\text{hr/year}) = \text{hr/fail}$$

This MTBF is used as the exponential failure rate input for the simulation, and converted back to BRF when necessary to determine COSAL support.

3. Figure of Merit Results

Several simplifying assumptions are made by using TIGER to obtain the output availability measure. The most important are exponential failures; BRF converted to MTBF; zero repair times; a full allowance of spares onboard at the beginning of the mission; and the use of a 'typical' reliability block diagram configuration for the duration of a single mission. Because of these assumptions, the availability figure provided by TIGER should not be considered as the true value for system availability. However, this figure

should be useful as a 'Figure of Merit' for comparisons with the figure derived for the same system using a different methodology or level of logistics support. When used in this context, the figure should provide an accurate assessment of the relative effectiveness of two spares allowance policies.

VI. EXAMPLE OF TIGER ANALYSIS

A. EQUIPMENT CONFIGURATION AND FAILURE RATES

1. Block Diagram and Operating Rules

As an example of the use of TIGER proposed in this thesis a hypothetical video display unit will be analyzed. The unit consists of a power section; signal processing section; and video display section. The required reliability block diagram is shown in figure 4.

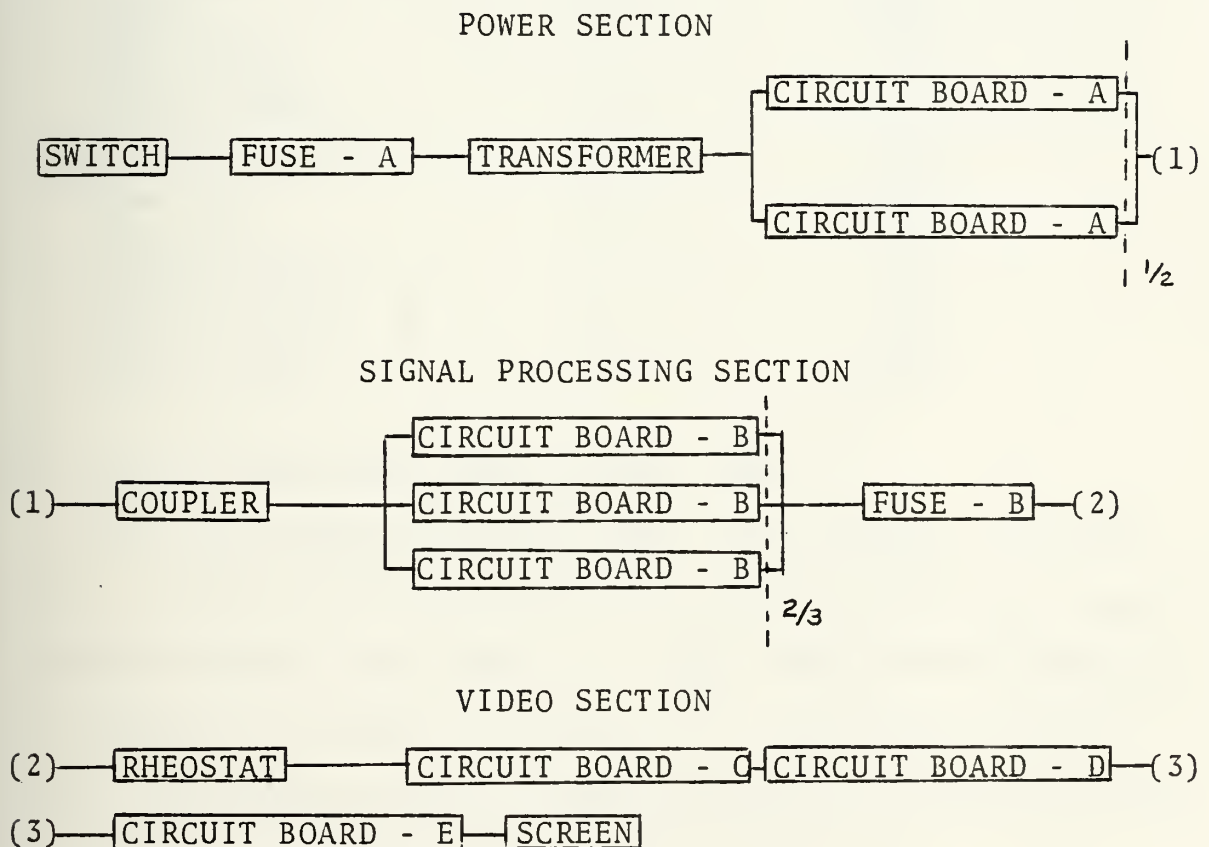


Figure 4

The three sections are connected in series to form the entire unit. Only one of circuit board A is required to be 'up' in the power section, and two of circuit board B in the signal processing section. The failure of two of either circuit board A or B or the failure of any other single part will cause system failure.

2. Failure Rates

The following is a list of the BRF for each part and corresponding MTBF:

<u>ITEM</u>	<u>BRF</u>	<u>MTBF</u>
Switch	.09	97400
Fuse - A	2.50	3506
Transformer	.17	51565
Circuit Board - A	2.10	4174
Coupler	.23	38113
Circuit Board - B	2.50	3506
Fuse - B	3.60	2435
Rheostat	.12	73050
Circuit Board - C	1.20	7305
Circuit Board - D	2.20	3985
Circuit Board - E	1.70	5156
Video Screen	.20	43830

B. LOGISTIC SUPPORT (COSAL) MODELS USED

The COSAL models evaluated were the standard .25 FLSIP and a modified FLSIP as proposed by the CNO Shipboard Parts Allowance Policy Study (Ref. 3). This modification consists of changing the FLSIP cut point to .1 (one demand in ten years) and providing an allowance quantity of two (vice one) for those items with a BRF between 2.0 and 4.0.

C. RESULTS OF ANALYSIS

1. Results of TIGER Simulation

The following tables provide a summary of the relevant output from the two TIGER simulation runs for 90 day missions. The actual computer output is self explanatory and a sample is included as a separate section of this thesis. The percent unavailability column indicates the percent of unavailability caused by each item.

.25 FLSIP (Availability = .7229)

ITEM	SPARES STOCKED	SPARES USED	FAIL/ MISSION	PERCENT UNAVA
Switch	0	.00	.025	3.35
Fuse - A	1	.50	.637	14.54
Transformer	0	.00	.042	6.42
Cir Bd - A	2	.96	1.05	6.77
Coupler	0	.00	.064	9.35
Cir Bd - B	4	1.84	1.897	.81
Fuse - B	1	.57	.793	24.01
Rheostat	0	.00	.030	3.74
Cir Bd - C	1	.27	.318	3.64
Cir Bd - D	1	.43	.541	11.99
Cir Bd - E	1	.34	.416	7.07
V. Screen	0	.00	.052	8.29
			<u>5.865</u>	<u>99.98</u>

.1 MOD FLSIP (Availability = .9064)

ITEM	SPARES STOCKED	SPARES USED	FAIL/ MISSION	PERCENT UNAVA
Switch	0	.00	.017	8.53
Fuse - A	2	.59	.607	5.41
Transformer	1	.05	.054	.75
Cir Bd - A	2	.92	1.015	24.70
Coupler	1	.06	.067	1.23
Cir Bd - B	4	1.84	1.897	2.58
Fuse - B	2	.79	.844	18.19
Rheostat	1	.04	.044	.00
Cir Bd - C	1	.27	.310	13.43
Cir Bd - D	2	.53	.553	5.42
Cir Bd - E	1	.35	.414	18.99
V. Screen	1	.04	.046	.74
			<u>5.868</u>	<u>99.97</u>

2. Interpretation of Results

As would be expected, the .1 Mod FLSIP provided a greater depth and range of spares than the .25 FLSIP. The addition of seven more spares resulted in an increase in AVA from .7229 to .9064, a significant increase. For the .25 FLSIP run, the item accounting for highest percentage of availability is fuse - B, with 24.01 percent. Since FLSIP provides a 90 percent confidence level of protection for those items with a BRF ≥ 4.0 ($\geq 1/\text{qtr}$), the BRF of 3.60 places the fuse just below this cut and therefore it is allocated only one spare. For the .1 Mod FLSIP run fuse - B no longer is the largest contributor to unavailability. Circuit board - A is the largest, accounting for 24.70 percent of the unavailability. If further incremental improvements were to be made to the .1 Mod FLSIP COSAL, the first additional spare should be circuit board - A followed by circuit board - B, fuse - B, and so on down the list of unavailability percentages.

The difference in AVA for the two COSALS is the most important statistic. If availability in the range of .9 were required for the system, the .1 Mod FLSIP should be used. If however, the system were not that essential, the .7 availability provided by FLSIP should be used to enable scarce spares funding resources to be used on more essential systems.

VII. SUMMARY AND CONCLUSIONS

This thesis focused on one basic problem; that of providing logistics support for Naval units afloat. Current guidelines and measures of effectiveness were presented along with several of the methodologies by which the policies are being carried out.

The NAVSEA TIGER reliability block diagram simulation program was introduced as a currently used method of evaluating ship reliability and also as a proposed method of generating allowance documents. A key input to any reliability calculation is the MTBF. The use by the Navy of a BRF vice MTBF was reviewed and a solution proposed to enable BRF to be used as an input to the TIGER simulation.

A technique for using TIGER to evaluate the effect of various spares allowance policies upon system availability was introduced, followed by an example of such an analysis.

The Navy is interested in providing logistics support so as to maximize the operational availability of its ships within given resource constraints. Mathematical models designed to allocate spares while maximizing system availability require extensive amounts of data (much of which is either not available or retrievable by computer). They are computationally infeasible to implement on a Navy-wide basis. Thus, it appears that the Navy will continue to use simpler

parts-counting models such as those described in this thesis. No claim of optimality with respect to 'system availability' can be made with such simple models that make no attempt to consider the system as anything other than a collection of parts.

The models that are being used are regulated by controlling the values of certain parameters such as FLSIP cut points or essentiality codes. Since there is no way to analytically relate these models to system effectiveness, a tool such as the TIGER simulator is needed to evaluate the future impact on system availability of a given provisioning or support policy. The assumptions required to perform this type of evaluation have been discussed throughout this thesis.

The following are recommendations for additional work in the topic of this thesis or for additional uses of the TIGER simulation:

- ✓ 1. Use as an evaluation tool for various provisioning models.
2. Use to evaluate maintenance policies and their effect on required manning levels.
3. Use as a system design tool.
4. Use on new equipment being introduced into the fleet to establish a FLSIP cut point. Code equipment with this cut point instead of the vital/non-vital codes currently in use, and use this cut point when preparing the COSAL.

5. Evaluate the effect of the assumptions made in this thesis and other problems such as the gradual degradation of equipment (not simply up or down) and the effect of the annual revisions to the BRFs.

APPENDIX A

ACRONYMS

Ao	Operational Availability
AVA	Availability
BRF	Best Replacement Factor
COSAL	Coordinated Shipboard Allowance List
CNO	Chief of Naval Operations
EST	Estimate
FBM	Fleet Ballistic Missile
FFG	Guided Missile Frigate
FLSIP	Fleet Logistics Support Improvement Program
MCO	Maintenance Criticality Oriented
MEC	Military Essentiality Code
MRU	Minimum Replacement Unit
MTBF	Mean Time Between Failure
MTTF	Mean Time to Failure
MTTR	Mean Time to Repair
NAVSEA	Naval Sea Systems Command
NPS	Naval Postgraduate School
PMR	Preventative Maintenance Requirement
RED	Readiness
REL	Reliability
RMA	Reliability/Maintainability/Availability

SPCC	Ships Parts Control Center
SSN	Fast Attack Submarine (Nuclear)
TIGER	Simulation Program Name
TOR	Technical Override

APPENDIX B

TIGER PROGRAM VARIABLES LIST

The following is a list of the variables used in the TIGER program and their respective usage/definition. All variables which were used in this thesis are included along with some from other optional parts of the TIGER program. Numbers at the right indicate the data card on which the variable is input into the program.

A	Subroutine DEMO producer risk	21A
ACMMH	Average corrective manhours per mission	
ADT	Administrative delay time	
AENDT1	Downtime in remainder of phase due to abort	
AENDT2	Downtime in remainder of mission due to abort (up to current phase)	
AFM	Average failures per mission	
ALDONE	Sum of three DONE(I); if zero, skips spare printout	
APPL	Bad apple unreliability and unavailability printout	21
AVA	Average availability or availability	
AVAINS	Instant availability	
AVA1	Average availability	
AVAL	Average availability	
AVGCST	Average cost per hour of repairman	7M
B	Subroutine DEMO consumer risk	21A

BAPRIN	Bad Apple printout indicator, when equals -1, print	
BILL	Temporary variable used to integerize the number of spares	
BLNK	Four character alphabetic blank	
COUNTB(I)	Number of failures for equipment I	
DAY(IX)	Occupation symbol	15A,M
DELT	Time Difference	
DEMO	Probability ratio test plan for system	21
DMNO	Same as DEMO	
DNT1	Total system downtime in phase	
DNT2	Total system downtime in mission	
DONE(I)	Average number of spares used from ship, tender, depot(I=1,3)	
DUM(J)	Dummy variable to read F1	
DUMMY	Skill types	
ENDPHA	End of phase time	
EQUIP(I)	Person type numbers of people who could be operating this type of equipment	15G
ETIME	Event time	
EX(I,J)	Administrative delay time (U,W)	
F(I,J)	Same as F1	
FCOUNT	Real value of JCOUNT	
F1	Alphabetic equipment description	8
GMMA	Alphabetic request for GAMMA subroutine	21
HAD	DEMO X-axis accept intercept	21A
HRD	DEMO X-axis reject intercept	21A
I	Various indices; equipment type number	8

IABC	Index	
IAUP	Instant availability (up for entire simulation)	
IAUP1(I)	Instant availability (up at beginning of sequence)	
IAUP2(I)	Instant availability (cumulative up at beginning of sequence)	
IB(I)	Group number and equipment and groups which make up the group	18
IBLANK	14 alphabetic blank spaces	
IBM	Equipment type number	
IBNUM(I,J)	Number of configuration matrix cards in phase	
ICHLD	Child in reliability tree	
ICRI	Subsystems exceeding mission allowable downtime (TAD2)	
ID	Alphabetic system name	16,17
IDIFF	Total equipment failures (all types)	
IDUM	Same as IUT	
IEQ	Absolute value of IEQU(J)	
IEQU(I)	Equipment type array	
IFF	Number of failures	
IFFEOP	Same as ISW	
IFLAG	Repair option in each phase	6
IFR	Number of repairs	
IGRP	Equipment group	
II	Spare location (ship, tender, depot)	
III	II-1	
IIUSED(I,J)	Spares used per equipment type from each location	

IK	Phase indicator	
IK2	Phase indicator	
IK3	Phase indicator	
ILB	Counter for NEQ	
ILL	Phase subscript for VDC(IU,ILL)	
IND	Equipment type	
INDEX	Index; equipment number	
INEWA	Index used to rank equipment by number of failures	
INMI(I)	Number of missions run	
INOABT(I)	Number of aborts in the sequence	
INREJ	Not used	
INUM	Maximum number of mission repetitions (50)	
IOR	Number of equipment operating rules	
IPTR	Parent/Child index	
IPRNT	Parent reliability tree	
IRULE	Equipment operating rule card	19
ISEED	Random number seed	2
ISO	+=string; -=standby	
ISPARE(I,J)	Quantity of spares at ship, tender, depot	15
ISS	System/subsystem identification number	16,17
ISSA(I)	Phase allowable downtime	
ISTB(I)	Equipment operating rules	19
ISUM	Summation	
ISW	Subsystem status (1=up, -1=down)	
ISSC	Subsystems exceeding allowable downtime	

ISYS(K)	System in phase K	
ITEMP	System status indicator	
ITEMP2	Subsystem status indicator	
ITIME	Number of sets	21A
ITER	Number of simulations per set	21A
ITOTAL	Integer value of total	
IU	Variable duty cycle (IUI(I))	
IUI(I)	Variable duty cycle indicator	8
IUNLIM	Alphabetic 'unlimited spares'	
IUT	Same as IDUM	
IUSED(I,K)	Spares used from ship, tender, depot	
IV	Variable duty cycle indicator (IUI=IV)	9
IVALUE(I)	Temporary variable for IB or ISTB	
IX	NUM+1	
IXX	Equipment type	
IXXT	Phase type	
J	Various indices; equipment type	
JA	Index for IB	
JB	Index for IB	
JBB	Phase sequence number	
JBB1	JBB-1	
JC	Current timeline	
JCC	Number of timelines	1
JCOUNT	Number of failed equipments	
JIND	Equipment type	
JNUM	Integer of XNUM	

K	Various indices	
KAA	Mission number being simulated	
KAB	Mission number being simulated	
KD	Trucation line accept	
KEQ	Equipment number	
KEQU(I)	Number of failures for equipment type I	
KID	Dummy variable	
KID1	Equipment group	
KID2	Equipment group	
KK	Same as LL; index of equipment number	
KKK	Phase in mission	
KKK2	Same as KKK	
KOPT	Printout option switch	5
KS(I)	Output options for KOPT	5
KSS	Index	
KT	IB(, ,1), or number required up in group	
K1	Equipment type; trail shape parameter	
L	Same as LL	
LCL	Lower confidence limit	
LL	Phase type number	16,17
LLL	Duration of phase sequence	
LOAD(I)	Equipment numbers assigned to equipment type	12
MAXIB	Maximum number of configuration matrix cards (300)	
MAXNEQ	Maximum number of equipments (500)	
MAXNPH	Maximum number of phases (6)	

MAXRUN	Maximum number of mission (1000)	
MAXSEQ	Total number of phases	
MAXSS	Maximum number of subsystems (31)	
MAXSTD	Maximum number of equipment operating rule cards (49)	
MAXTYPE	Maximum number of equipment types (200)	
MDT	Estimator of MTTR	
MKBA	Bad Apple equipment vector	
MM	0	
MTBMF	Mean time between mission failures	
MUT	Instantaneous MTBF parameter	
M1	Trial scale parameter	
N	Counter; NSS+1	
NEQ	Equipment type counter	
NLINE(I)	Number of configuration cards in phase	
NL1	NLINE(LL)	
NN	Index	
NMAX	Maximum number of missions	2
NOPT	Optimal number of mission	2
NPH	Number of phases	2
NRO	Number required operating	18
NSS	Number of subsystems in phase	16
NTY	Last number of equipment types	
NTYPE	Equipment type	12
NT1	Equipment type number	
NUM	Mission number counter	

PERC	Percent unreliable	
PL	Reliability specification	2
R	Dummy variable used to find next event temporary variable used to calculate VDC; discrimination ratio	21A
RDT	Running down time	
RED	Readiness	
REDAD1(I)	Adjusted time for readiness calculation in phase	
REDAD2	Adjusted time for readiness calculation in mission	
RED1	Readiness	
RED2	Readiness	
REL	Reliability	
RELGA(JBB)	Reliability (RELPY) for phase sequence	
RELPY	Reliability up to and including phase just completed	
REPOL	Percent of repairs performed aboard ship	7
RN	Random number	
RN3	Random number	
RUNID	Alphabetic program identification line	1
SLD	Slope	21A
SPRS	Alphabetic request for SPARES output	21
SR	Intermediate value used to calculate ST	
SSTIME(I,J)	System/subsystem allowable sustained downtime	16,17
ST	Intermediate time	
STEPHAS	Accumulated phase time	
SUMX	Total simulation time	

SUMX2	Sum of SUMX squared (for variance calculation)	
SX	Spares multiplier	
T	Duration of phase	
TABORT	Time of abort	
TACMMH	Total average corrective maintenance manhours/mission	
TAD1	Same as SSTIME	
TAD2	Mission allowable downtime	7
TAFM	Total average failures per mission	
TDEOP	Time down at end of phase	
TDOWN	Time system went down	
TIMA(I)	Cumulative phase time	
TIME	Simulation clock time	
TITLE(K,N)	Alphabetic subsystem title	
TNMI	Real value of INMI(JBB)	
TOTAL	Number of failed missions	
TR	Temporary variable used to find maximum unavailability/reliability	
TRR	Same as TR	
TP	Same as TIME	
TTEMP	Downtime	
TTF	Time for failure	
TTR	Time to repair	
TT1	Phase length	
TT2(JBB)	Cumulative time of phase lengths	
TT3	Cumulative phase times	

TYCOON(I)	Downtime for equipment	
TYCUM	Unavailability	
TYCUM2	Percent unavailability	
T1	SSTIME(, ,1)	
T3	Downtime	
T3SUM	Cumulative downtime	
U	Duty cycle utilization	8
UNAVA	Unavailability	
UNREL	Unreliability	
UP1	Time system up in phase	
UP2(JBB)	Cumulative system uptime	
UP3	Cumulative system uptime	
UP4	Cumulative system uptime	
V	Administrative delay time (tender to ship)	8
VAR	MTBMF variance	
VDC(I)	Duty cycle utilization during each phase	9
VMTTR(I,J)	Variable mean time to repair	10
W	Administrative delay time (depot to ship)	8
X	Various; XMTBF; event indicator (+ fail; - repair)	
XAV	Instant availability	
XAVI	Instant availability	
XCUM	Successful missions in last 50	
XDWN	Number of mission failures (XNUM-XTCUM)	
XIAUPP	Real of IAUP	

XIAUPI	Real of IAUPI	
XID	Alphabetic ID	
XIFF	Real of IFF	
XIRR	Real of IRR	
XK	Standard deviation for lower confidence limit 2	2
XKAA	Real of KAA	
XLCLA	Lower confidence limit of 90 percent	
XM	XMTBF Multiplier	7
XMDT	System man down time	
XMTBA	Mean time between mission failures	
XMTBF	Mean time between failures	8
XMTTR	Mean time to repair	8
XMUT	System mean up time	
XM1	Same as XT	
XNO	Number of non aborts	
XNUM	Real of NUM (total missions run)	
XPCAP	Reliability	
XPLCL	Lower confidence limit	
XT	XMTBF multiplier	7
XTABT(I)	Time of abort mission I	
XTCUM	Cumulative successful missions	
XXT(I)	Phase type (I odd); Duration (I even)	3
XXX	XMTBF or VMTTR	
X2	X squared	
Y	Same as XMTTR	
YD	Truncation line accept	21A

APPENDIX C

SPARES SUBROUTINE VARIABLE LIST

CUT	FLSIP cut point
DUM	Dummy variable
EX90DD	Expected 90 day demand
ITMPOP(I)	Number of equipment type I in reliability block diagram
K	Counter
KFACT	K factorial
PRBSUM	Poisson probability summation
SPR1-14	Various user defined input variables

APPENDIX D

MODIFICATIONS TO TIGER PROGRAM INPUT

To use the GAMMA and DEMO options, the end of the main section of the program must be changed to the following:

```
1210 IF (GMMA.EQ.BLNK) GO TO 1230
```

```
1220 CALL GAMMA
```

```
1230 CONTINUE
```

```
    IF (DMNO.EQ.BLNK) GO TO 1240
```

```
    CALL DEMO
```

```
1240 STOP
```

```
END
```

Subroutine GAMMA, function GAMF, subroutine DEMO, function CHISQ, subroutine TGEN, and subroutine CKTP must be added to the program deck (note: none of these have been utilized or verified for use on the NPS computer).

The following changes were made to the original input deck:

Card 2 - INREJ replaced by ISEED; the random number generator seed.

Card 14 - If spares subroutine is desired, enter 999. for SX. Fourteen variables (SPR1, SPR2, ..., SPR14) may then be read into the spares subroutine in F4.0 format starting in column 25.

These changes are incorporated into the input requirements shown on the following pages. They should be used when preparing the TIGER data input deck.

All integer fields must be right justified

<u>Columns</u>	<u>Format</u>	<u>Variable Name</u>	<u>Description</u>
----------------	---------------	----------------------	--------------------

(1) Timeline Iteration Card

1-4	I4	JCC	No. of timeline variations to be run for the data deck. If JCC exceeds 1, only phase type and duration card(s) must be added in the back of the data deck, followed by a blank card.
5-80	19A4	RUNID	Alphanumeric run identifier.

(2) Statistical Parameter Card

1-4	I4	NMAX	Maximum number of missions to be run (should be in multiples of 50 and must not exceed 1000)
5-8	I4	NOPT	Optimal number of missions (not to exceed NMAX).
9-12	F4.0	PL	Specification requirement for reliability.
13-16	F4.0	XK	Standard deviation to be used in calculating lower control limit.
17-20	I4	ISEED	Random number seed.
21-24	I4	NPH	No. of phase types--not to exceed 6.

NOTE: - If a predefined fixed number of missions is to be run, set PL =1.0, and NOPT and NMAX to the desired number of missions.

<u>Columns</u>	<u>Format</u>	<u>Variable Name</u>	<u>Description</u>
<u>(3) Phase Type and Duration Card(s)</u>			
1-2	F2.0	XXT(1)	Phase type number for first simulation sequence.
3-10	F8.0	XXT(2)	Duration of first sequence.
11-12	F2.0	XXT(3)	Phase type number for second simulation sequence (if any).
13-20	F8.0	XXT(4)	Duration of second sequence.
21-22	F2.0	XXT(5)	Phase type number for third simulation sequence (if any).
23-30	F8.0	XXT(6)	Duration of third sequence.
31-32	F2.0	XXT(7)	Phase type number for fourth sequence (if any).
33-40	F8.0	XXT(8)	Duration of fourth sequence.
41-42	F2.0	XXT(9)	Phase type no. for fifth sequence (if any).
43-50	F8.0	XXT(10)	Duration of fifth sequence.
Note: If more than 5 phase sequences are needed, continue on additional cards using the same fields. No more than 95 phase sequences are permitted.			

(4) *****Blank Card*****

<u>Columns</u>	<u>Format</u>	<u>Variable Name</u>	<u>Description</u>
----------------	---------------	----------------------	--------------------

(5) Printout Option Card

1-4	I4	KOPT	
-----	----	------	--

Printout option switch
 = 1 for management summary printout.
 = 2 for engineering summary printout.
 = 3 for TIGER complete details printout.
 (For debugging only)
 = 4 to suppress printout of input data.
 = 5 to specify printout using the KS
 variables (see below)
 = 6 for TIGER/MANNING complete details
 printout. (For debugging only).

If KOPT=5, select from the following output options as needed (otherwise leave the field(s) blank):

5-8	I4	KS(1)	= 1: Input Data
9-12	I4	KS(2)	= 1: equipment down at time of mission failure.
13-16	I4	KS(3)	= 1: down time at end of phase.
17-20	I4	KS(4)	= 1: abort messages.
21-24	I4	KS(5)	= 1: all events.
25-28	I4	KS(6)	= 1: ETIME Matrix. (For debugging only.)
29-32	I4	KS(7)	= 1: Not used.
33-36	I4	KS(8)	= 1: Not used.
37-40	I4	KS(9)	= 1: Not used.
41-44	I4	KS(10)	= 1: System & subsystem status.
45-48	I4	KS(11)	= 1: TIGER/MANNING denugging printout.

<u>Columns</u>	<u>Format</u>	<u>Variable Name</u>	<u>Description</u>
<u>Printout Option Card (Cont.)</u>			
49-52	I4	KS(12)	= 1: Status of all groups
53-56	I4	KS(13)	= 1: Downtime message.
<u>(6) Phase Repair Card</u>			
1-4	I4	IFLAG(1)	Repair option for each phase type, up to 6: = 0 if on-board repair allowed in the phase. = 1 if no on-board repair allowed. = 2 if on-board repair allowed but failure inhibited.
5-8	I4	IFLAG(2)	
9-12	I4	IFLAG(3)	
13-16	I4	IFLAG(4)	
17-20	I4	IFLAG(5)	
21-24	I4	IFLAG(6)	
<u>(7) Repair Policy Card</u>			
1-4	F4.0	REPOL	Decimal fraction of repairs to be performed aboard ship, i.e. organizational level.
5-12	F8.2	TAD2	Mission allowable downtime
13-16	F4.0	XM	MTBF Multiplier. Default = 1.0
17-20	F4.0	XT	MTTR Multiplier. Default = 1.0

<u>Columns</u>	<u>Format</u>	<u>Variable Name</u>	<u>Description</u>
(8) <u>Equipment Type Cards (one card for each equipment type)</u>			
1-4	I4	I	Equipment type numbers - should be assigned sequentially starting at 1, not to exceed 200.
5-20	4A4	F1	Equipment type description/nomenclature.
21-28	F8.0	XMTBF	Mean time between failure (MTBF).
29-32	F4.0	XMTTR	Mean time to repair (MTTR). Precede by negative sign and include the variable MTTR card if variable MTTR option desired. Non-repairable is indicated by a value of 9999.
33-36	F4.0	U	Duty cycle/Utilization (non-zero decimal fraction).
37-40	F4.0	V	Administrative delay time from tender to ship.
41-44	F4.0	W	Administrative delay time from depot to ship.
45-48	I4	IUI	If a variable duty cycle (VDC) for this equipment type is desired, assign a sequential number (between 1 and 50) and include the VDC card following. Otherwise leave this field blank.

<u>Columns</u>	<u>Format</u>	<u>Variable Name</u>	<u>Description</u>
(9)	<u>Variable Duty Cycle (VDC) Card</u>		
1-4	I4	IV	(Optional - If IUI on previous type card is non-zero, place this card immediately behind the type card to which it refers. A maximum of 50 VDC cards per deck are allowed.)
5-8	F4.0	VDC(1)	VDC Identifier-sequential number, same as the value of IUI on the preceding equipment type card.
9-12	F4.0	VDC(2)	Duty cycle/utilization of the equipment type during each phase type 1-6. These values override the value of U on the preceding Equipment Type Card.
13-16	F4.0	VDC(3)	
17-20	F4.0	VDC(4)	
21-24	F4.0	VDC(5)	
25-28	F4.0	VDC(6)	

(10)	<u>Variable Mean Time to Repair (MTTR) Card</u> (Optional - If XMTR is negative on the Equipment Type Card place this card behind the VDC Card or, if there is no VDC Card, behind the Equipment Type Card.)		
1-4	F4.0	VMTR(1)	MTTR values of the equipment type during each phase type 1-6. Non-repairable is indicated by 9999.

<u>Columns</u>	<u>Format</u>	<u>Variable Name</u>	<u>Description</u>
<u>Variable Mean Time to Repair (MTTR) Card (Cont.)</u>			
5-8	F4.0	VMTTR(2)	
9-12	F4.0	VMTTR(3)	
13-16	F4.0	VMTTR(4)	
17-20	F4.0	VMTTR(5)	
21-24	F4.0	VMTTR(6)	

(11) *****Blank Card***** (This indicates the end of the equipment type cards.)

(12) Equipment Cards (One for each equipment type - Place sequentially by type number)

1-4	I4	NTYPE	The type number associated with the equipment listed in the next field(s).
5-8	I4	LOAD(1)	Equipment numbers of those equipment which belong to the designated equipment type - up to 19 equipment per card (if there are more than 19 equipment associated with a given type, use additional equipment cards and repeat the same type number). The largest equipment number allowed by the program is 500. The total number of equipment must not exceed 500. No gaps are allowed between equipment number 1 and the largest assigned equipment number.
9-12	I4	LOAD(2)	
13-16	I4	LOAD(3)	
17-20	I4	LOAD(4)	
21-24	I4	LOAD(5)	
25-28	I4	LOAD(6)	
29-32	I4	LOAD(7)	

<u>Columns</u>	<u>Format</u>	<u>Variable Name</u>	<u>Description</u>
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Equipment Cards (Cont.)

33-36	I4	LOAD(8)	
37-40	I4	LOAD(9)	
41-44	I4	LOAD(10)	
45-48	I4	LOAD(11)	
49-52	I4	LOAD(12)	
53-56	I4	LOAD(13)	
57-60	I4	LOAD(14)	
61-64	I4	LOAD(15)	
65-68	I4	LOAD(16)	
69-72	I4	LOAD(17)	
73-76	I4	LOAD(18)	
77-80	I4	LOAD(19)	

(13) *****Blank Card***** (This indicates end of equipment cards.)

(14) Blank Card or literal "UNLIMITED SPARES" starting in column 1. If Blank Card is used then the spares multiplier (SX) may be inserted in Col. 21-24. The format for SX is F4.0 and the default value is 1.0; Use 999. to call SPARES subroutine. Variables SPR1-SPR14 may be inserted in F4.0 format starting in Col, 25.

<u>Columns</u>	<u>Format</u>	<u>Variable Name</u>	<u>Description</u>
(15) <u>Spares Cards</u>			(Omit if unlimited spares specified above. One spares card for each equipment type-program assumes these cards are in sequential order starting with Type 1)
1-4	I4	ISPARE(1)	Number of organizational level spares (on-board) for the equipment type.
5-8	I4	ISPARE(2)	Number of spares at the tender for the equipment type.
9-12	I4	ISPARE(3)	Number of spares at the base (depot) for the equipment type.

NOTE: For each phase type, a set of the remaining cards (except the optional output and demo cards which appear once) must be placed consecutively in the data deck.

(16) <u>System Card</u>			
1-4	A4	ID	Any alphanumeric, e.g., the literal "SYST"
5-8	I4	LL	Phase type number (sequential) - Maximum value is 6.
9-12	I4	NSS	Number of subsystems in the phase (varies only from 1 to 31)
13-16	I4	ISS	System identification number (usually last group number on the configuration matrix cards).

<u>Columns</u>	<u>Format</u>	<u>Variable Name</u>	<u>Description</u>
<u>System Card (Cont.)</u>			
17-24	F8.0	SSTIME	System allowable sustained down time TAD1 (should not be less than subsystem TAD1 values). This value should be less than or equal to TAD2 (Repair Policy Card). To inhibit aborts use a value of 100000.
<u>(17) Subsystem Cards</u> (One for each subsystem - up to 31.) At least one subsystem is required.			
1-4	A4	ID	Any alphanumeric, e.g., the literal "SS1", "SS2", ... "SS31".
5-8	I4	LL	Phase type number.
13-16	I4	ISS	Subsystem identification number. This is a group number for a group defined on a Configuration Matrix Card (see below). Each designated subsystem group must be a group that, upon its failure, causes the system to fail.
17-24	F8.0	SSTIME(2)	Subsystem allowable sustained down time (TAD1). This value should be less than or equal to SSTIME on the System Card. To inhibit aborts use a value of 100000.

(18) Configuration Matrix Cards (One card for each group, up to 300 cards)

1-4	I4	NRO	The number of members in the group defined on this card that are required to be operating and in an upstate.
5-8	I4	IB(1)	The group number assigned to the group of members defined on this card. It may vary from 501 to 1000 in any order.
9-12	I4	IB(2)	The numbers of the equipment and groups which make up the group defined on this card. The maximum number of members in a group is unlimited; however, if there are more than 7, a continuation card is required, which is of the same format. The number required and master group number must be identical on all continuation cards.
13-16	I4	IB(3)	
17-20	I4	IB(4)	
21-24	I4	IB(5)	
25-28	I4	IB(6)	
29-32	I4	IB(7)	
33-36	I4	IB(8)	

(19) Equipment Operating Rule Cards

(Optional - Usually this card is placed immediately behind the configuration matrix card which refers to the equipment and groups on this card.)

These cards indicate the equipment operating rules for string or standby equipment. The string equipment operating rule causes shutdown of a designated series equipment upon failure of any of the other equipment or equipment groups on the card. The standby

<u>Columns</u>	<u>Format</u>	<u>Variable Name</u>	<u>Description</u>
<u>Equipment Operating Rule Cards (Cont.)</u>			
1-4	I4	ISTB(1)	equipment operating rule causes designated equipment to be energized upon failure of any of the other equipment or equipment groups on the card. The maximum number of equipment operating rules is 49. (One rule defined per card.)
5-8	I4	ISTB(2)	
9-12	I4	ISTB(3)	
13-16	I4	ISTB(4)	
17-20	I4	ISTB(5)	
21-24	I4	ISTB(6)	
25-28	I4	ISTB(7)	
29-32	I4	ISTB(8)	
33-36	I4	ISTB(9)	
37-40	I4	ISTB(10)	
41-44	I4	IRULE	Place any non-zero integer in this field (to distinguish Equipment Operating Rule Cards from Configuration Matrix Cards).

(20) *****Blank Card***** (This indicates end of phase configuration and operating rules.)

(21) Optional Output Card (Optional - Appears once in computer job deck)

1-4	A4	SPRS	Place any alphanumeric, e.g., "SPR", in this field if a table of spares usage is desired.
5-8	A4	APPL	Place any alphanumeric, e.g., "APL", in this field if a summary table of equipment that caused mission failures (unreliability) and system down times (unavailability) is desired.
9-12	A4	GMMA	Place any alphanumeric, e.g., "GMA", in this field if the gamma distribution output is desired.
13-16	A4	DEMO	Place any alphanumeric, e.g., "DEMO", in this field if a sequential probability ratio test plan for the system being analyzed is desired. If this option is exercised, an additional card, 21A, is required.

(22) DEMO Information Card (Optional - must be included if DEMO is specified on the Optional Output Card.)

1-4	F4.0	A	Producer Risk.
5-8	F4.0	B	Consumer Risk

<u>Columns</u>	<u>Format</u>	<u>Variable Name</u>	<u>Description</u>
<u>DEMO Information Card (Cont.)</u>			
9-12	F4.0	R	Discrimination Ratio.
The following are optional inputs:			
13-16	F4.0	HAD	X-Axis accept intercept (Delta).
17-20	F4.0	HRD	X-Axis reject intercept (Delta).
21-24	F4.0	YD	Trucation line accept (Delta).
25-28	F4.0	SLD	Slope (Delta).
29-32	I4	KD	Truncation line reject (Delta).
33-36	I4	ITIME	Number of sets (explained in Appendix C).
37-40	I4	ITER	Number of simulations per set.
41-44	I4	N	Random number initializer.

TIGER COMPUTER OUTPUT (SAMPLE)

EQUIP. FAILURES EQUIP. NO.	AND CORRECTIVE TYPE NO.	MAINTENANCE (CM) TOTAL EQUIP. FAILURES	AVG. NO. FAILURES PER MISSION	SUMMARY NO. FAILURES PER MISSION	AVG. CM MANHOURS PER MISSION
1	1	25	0.025	0.025	0.0
2	2	637	0.637	0.637	0.0
3	3	42	0.042	0.042	0.0
4	4	525	0.525	0.525	0.0
5	4	525	0.525	0.525	0.0
6	5	64	0.064	0.064	0.0
7	6	636	0.636	0.636	0.0
8	6	582	0.582	0.582	0.0
9	6	679	0.679	0.679	0.0
10	7	793	0.793	0.793	0.0
11	8	30	0.030	0.030	0.0
12	9	318	0.318	0.318	0.0
13	10	541	0.541	0.541	0.0
14	11	416	0.416	0.416	0.0
15	12	52	0.052	0.052	0.0
		5865	5.865	5.865	0.0

AVERAGE NUMBER OF SPARES USED PER MISSION			TENDER		BASE	
SPARES TYPE	SHIP STOCK	USED	STOCK	USED	STOCK	USED
2	1	0.50	0	0.0	0	0.0
4	2	0.96	0	0.0	0	0.0
6	4	1.84	0	0.0	0	0.0
7	1	0.57	0	0.0	0	0.0
9	1	0.27	0	0.0	0	0.0
10	1	0.43	0	0.0	0	0.0
11	1	0.34	0	0.0	0	0.0

CRITICAL EQUIPMENTS
UNAVAILABILITY AND
PERCENT OF UNAVAILABILITY

NAME	NUM HRS	UNAVA	PERCENT	EQU TYPE	EQU NUM
FUSE - F	143678.1250	0.0665	24.01	7	10
FUSE - A	86987.9375	0.0403	14.54	2	13
CIRCUIT BD - D	71777.3125	0.0332	11.99	10	13
COUPLER SCREEN	55935.1875	0.0259	9.35	5	6
VIDEO CIRCUIT BD - E	49632.4648	0.0230	8.29	12	15
CIRCUIT BD - A	42291.3203	0.0196	7.07	11	14
TRANSFORMER	38421.7227	0.0178	6.42	3	3
CIRCUIT BD - A	24414.9922	0.0113	4.08	4	5
RHEOSTAT	22381.4844	0.0104	3.74	8	11
CIRCUIT BD - C	21809.4063	0.0101	3.64	9	12
SWITCH	20024.2852	0.0093	3.35	1	1
CIRCUIT BD - A	16121.3125	0.0075	2.69	4	4
CIRCUIT BD - B	1794.4338	0.0008	0.30	6	8
CIRCUIT BD - B	1640.1653	0.0008	0.27	6	7
CIRCUIT BD - B	1433.9836	0.0007	0.24	6	9

CRITICAL EQUIPMENTS
UNRELIABILITY AND
PERCENT OF MISSION FAILURES

DESCRIPTION	NO. FAILURES	UNREL	PERCENT	EQUIP TYPE	EQUIP NO.
FUSE - B	162.0	0.1620	26.30	7	10
FUSE - A	102.0	0.1020	16.56	2	12
CIRCUIT BD - D	178.0	0.0780	12.66	10	13
CIRCUIT BD - E	49.0	0.0490	7.95	11	14
COUPLER	48.0	0.0480	7.79	5	16
VIDEO SCREEN	34.0	0.0340	5.52	12	15
TRANSFORMER	30.0	0.0300	4.87	3	3
CIRCUIT BD - A	25.0	0.0250	4.06	4	5
CIRCUIT BD - A	24.0	0.0240	3.90	4	4
CIRCUIT BD - C	22.0	0.0220	3.57	9	12
RHEOSTAT	20.0	0.0200	3.25	8	11
SWITCH	15.0	0.0150	2.44	1	1
CIRCUIT BD - B	3.0	0.0030	0.49	6	8
CIRCUIT BD - B	2.5	0.0025	0.41	6	7
CIRCUIT BD - B	1.5	0.0015	0.24	6	9

TOTAL NO. MISSIONS=1000
TOTAL NO. MISSION FAILURES= 616

ACTUAL SET UP	MISSIONS WILL	BE RUN TO	OBTAIN REQUIRED	STATISTICAL CONFIDENCE.	EXCEEDED	MISSION	ALLOWABLE	DOWNTIME	HRS.
IN PHASE 1 SEQ EQUIPMENT	10	952	IT WILL COME UP AT	1685.5276	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	10	955	IT WILL COME UP AT	686.5900	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	6	956	IT WILL COME UP AT	358.8159	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	6	959	IT WILL COME UP AT	1491.3406	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	2	960	IT WILL COME UP AT	948.6260	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	13	961	IT WILL COME UP AT	1098.0498	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	2	962	IT WILL COME UP AT	1394.3967	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	2	963	IT WILL COME UP AT	37.7034	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	11	966	IT WILL COME UP AT	1703.9910	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	13	967	IT WILL COME UP AT	1030.7476	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	11	968	IT WILL COME UP AT	670.8741	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	2	969	IT WILL COME UP AT	920.3120	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	2	970	IT WILL COME UP AT	1631.5000	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	11	971	IT WILL COME UP AT	762.5000	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	5	975	IT WILL COME UP AT	1984.3504	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	5	976	IT WILL COME UP AT	1109.8431	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	2	977	IT WILL COME UP AT	1841.3823	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	5	978	IT WILL COME UP AT	555.3267	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	10	979	IT WILL COME UP AT	857.9833	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	10	980	IT WILL COME UP AT	1542.3799	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	10	981	IT WILL COME UP AT	909.8152	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	12	982	IT WILL COME UP AT	2122.6633	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	2	983	IT WILL COME UP AT	1103.8336	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	10	984	IT WILL COME UP AT	73.3333	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	5	988	IT WILL COME UP AT	945.3255	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	10	989	IT WILL COME UP AT	1239.5000	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	10	990	IT WILL COME UP AT	2102.9492	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	14	991	IT WILL COME UP AT	476.5080	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	15	994	IT WILL COME UP AT	1741.2859	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	2	995	IT WILL COME UP AT	1524.3369	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	10	997	IT WILL COME UP AT	1169.4402	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	10	999	IT WILL COME UP AT	870.4844	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	2	1000	IT WILL COME UP AT	415.2183	BECAUSE SYST	EXCEEDED	MISSION	ALLOWABLE	0.0
IN PHASE 1 SEQ EQUIPMENT	10		IT WILL COME UP AT	-500000.0000		EXCEEDED	MISSION	ALLOWABLE	0.0

RELIABILITY PHASE	1,	1,	IS 0.3840	INSTANT AVAILABILITY	IS 1.0000
READINESS			IS 0.7229	RELIABILITY UP TO PHASE	IS 0.3840
AVERAGE AVAILABILITY			IS 0.7229	READINESS	IS 0.7229
				AVERAGE AVAILABILITY	IS 0.7229
				INSTANT AVAILABILITY	IS 0.3840

A GRAND TOTAL OF 1000 MISSIONS HAVE BEEN RUN.

THE RELIABILITY IS 0.3840
 THE LOWER CONF LIMIT IS 0.3646
 THE SPEC REQUIREMENT IS 1.0000
 THE READINESS IS 0.7229
 THE AVERAGE AVAILABILITY IS 0.7229
 THE INSTANT AVAILABILITY IS 0.3840

THE MEAN TIME BETWEEN MISSION FAILURES IS 2534.9
 THE LCI 90 MTBMF IS 1033.9
 THE MTBMF VARIANCE IS 1375166.0

THE SYSTEM MUT IS 2535.0
 THE SYSTEM MDT IS 0.189
 SIMULATION COMPLETE-OPTIMUM NUMBER MISSIONS WERE RUN

TIGER IBM/360 FORTRAN IV COMPUTER PROGRAM

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C      ++++++ TIGER ++++++
C      ++++++ NAVSEC 6112 LUETJEN+MANDEL+VAIL+ALLEY+BROWN ++++++
C      +===== FEB 1979 =====
C
COMMON /ALPHA/DNT2,ENDPHA,ICRI,IFF,IFR,INUM,IOPT,JBB,KEQ,KKK,KZZ
1,KK1,KS1,LL,LLLAST,NEQ,NPH,NTYPE,NUM,REDAD2,REDAD1(100),RELP,RED2
2,RELPY,REPOL,STPHAS,TP,TLXCUM,TT3,UP3,IFFEOP,I3,TIME,I3SUM
COMMON/BETA/NRO(6,300),IB(6,300,8),NLINE(6)
COMMON/EXTRA/ KS(20),ISW(31)
COMMON/N/IEQU(500),KEQU(500),ETIME(1000),XMTBF(200),XMTTR(200)
COMMON/NPH/ NSS(6),IFLAG(6),TITLE(6,31),SSTIME(6,31,2),ISS(6,31)
COMMON/SEQ/INDABT(100),INMI(100),IAUPL(100),TT2(100),UP2(100)
1,IAUP2(100)
COMMON/TYP/EX(2,200),ISPARE(3,200),IUSED(3,200)
COMMON/ MAX/ MAXNEQ, MAXTYP, MAXIB, MAXSTD
COMMON/ GAMMA/ GAMMAA/ XMTBA, VAR, RELGA(100),TIMA(100),XTT(200),ITI,ISEED
COMMON/ TABORT/ XTABT(1000),ROT
COMMON/ TIGAP/ UP4,XNUM,BAPRIN,AVA,XPCAP,RUNID(19),TYCOON(500)
+ ,COUNTB(500),XTCUM
COMMON /DONE/DONE(3)
DATA BLNK/4H

MAXRUN=1000
MAXNPH=6
MAXSTD=50
MAXNEQ=500
MAXTYP=200
MAXIB=300
MAXSS=31
MAXSEQ=100
CALL OVFLOW
READ (5,10) JCC,(RUNID(1),I=1,19)
10 FORMAT(14,19A4)
WRITE (6,220) JCC
DO 1230 JC=1,JCC
20 WRITE (6,30) (RUNID(1),I=1,19)
30 FORMAT(1H1,30X,19A4//)
WRITE (6,40)
WRITE (6,50)
WRITE (6,55)
40 FORMAT(1X,50H ++++++ TIGER ++++++
50 FORMAT(/1X,50H++ NAVSEC 6112 LUETJEN+MANDEL+VAIL+ALLEY+BROWN ++ )
55 FORMAT(/1X,50H++NPS IBM/360 VERSION LT. J. LEATHER THESIS 9/80++ )
BAPRIN=0.0
DO 70 I=1,MAXNEQ
60 COUNTB(I)=0.0
TYCOON(I)=0.0

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70 KEQU(I)=0
   ETIME(I)=100000.
   IFF=0
   IFR=0
   UP4=0.0
   T3=0.0
   T3SUM=0.0
   SUMX=0.0
   SUMX2=0.0
   DO 80 I=1,100
80   TIMA(I)=0.
   DO 90 J=1,3
   DO 90 J=1,MAXTYP
90   IUSED(I,J)=0
   DO 100 I=1,MAXSEQ
   TT2(I)=0.0
   UP2(I)=0.0
   IAUP1(I)=0
   IAUP2(I)=0
   REDAD1(I)=0.0
   INMI(I)=0
100  INOABT(I)=0
   IAUP=0
   XTCUM=0
   IF (JC-1) 110,110,140
110  READ (5,120) NMAX,NOPT,PL,XK,I SEED,NPH
120  FORMAT (2I4,2F4.0,2I4)
130  FORMAT (1X2I6,2XF4.2,2XF5.2,2XI6,2XI4)
140  CONTINUE
160  WRITE (6,170) I SEED
170  FORMAT (//1X15HRANDOM SEED IS ,I4)
   IF (NMAX-MAXRUN) 190,190,180
180  NMAX=1000
   NOPT=1000
190  DO 200 I=1,NMAX
200  XTABT(I)=10000.
   WRITE (6,130) NMAX,NOPT,PL,XK,I SEED,NPH
   IF (MAXNPH-NPH) 1240,210,210
210  INUM=50
220  FORMAT (4I10)
230  DO 250 I=1,191,10
   READ (5,240) XXT(I),(XXT(I+J),J=1,9)
   IF (XXT(I)) 260,260,250
240  FORMAT (5(F2.0,F8.0))
250  CONTINUE
260  WRITE (6,270)
270  FORMAT (1H1,10X40PHASE SEQUENCE TYPE DURATION CUM TIME)

```


MAIN0960
 MAIN0970
 MAIN0980
 MAIN0990
 MAIN1000
 MAIN1010
 MAIN1020
 MAIN1030
 MAIN1040
 MAIN1050
 MAIN1060
 MAIN1070
 MAIN1080
 MAIN1090
 MAIN1100
 MAIN1110
 MAIN1120
 MAIN1130
 MAIN1140
 MAIN1150
 MAIN1160
 MAIN1170
 MAIN1180
 MAIN1190
 MAIN1200
 MAIN1210
 MAIN1220
 MAIN1230
 MAIN1240
 MAIN1250
 MAIN1260
 MAIN1270
 MAIN1280
 MAIN1290
 MAIN1300
 MAIN1310
 MAIN1320
 MAIN1330
 MAIN1340
 MAIN1350
 MAIN1360
 MAIN1370
 MAIN1380
 MAIN1390
 MAIN1400
 MAIN1410
 MAIN1420
 MAIN1430

```

IK=1
IK2=2*IK
IK3=IK2-1
IXXT=XXT(IK3)
TIMA(1)=XXT(2)
WRITE(6,280) IK, IXXT,XXT(IK2),TIMA(IK)
280 FORMAT(19X14,2XF8.2,2XF8.2)
DO 300 IK=2,100
IK2=2*IK
IK3=IK2-1
IF (XXT(IK2)) 290,310,290
290 TIMA(IK)=TIMA(IK-1)+XXT(IK2)
IXXT=XXT(IK3)
WRITE(6,280) IK, IXXT,XXT(IK2),TIMA(IK)
300 CONTINUE
310 CONTINUE
IF (JC-1) 320,320,330
320 CALL PACK
C
330 CONTINUE
JBB=1
RELPY=1.0
RELPI=1.0
UP3=0.0
TT3=0.0
REDAD2=0.0
DO 340 I=1,MAXSS
340 ISW(I)=1
ICRI=0
DNI2=0.0
STPHAS=0
T1=0.0
350
RDT IS RUNNING DOWNTIME
RDT=0.0
KKK = 0 INDICATES FIRST PHASE IN MISSION.
START OF MISSION INDICATION
IF (KS(8)) 380,380,360
360 KAB=NUM+1
WRITE(6,370) KAB
370 FORMAT(1X,16HSTART OF MISSION,15,20H*****
380 KKK=0
390 I=1
*****
)

```


MAIN1440
MAIN1450
MAIN1460
MAIN1470
MAIN1480
MAIN1490
MAIN1500
MAIN1510
MAIN1520
MAIN1530
MAIN1540
MAIN1550
MAIN1560
MAIN1570
MAIN1580
MAIN1590
MAIN1600
MAIN1610
MAIN1620
MAIN1630
MAIN1640
MAIN1650
MAIN1660
MAIN1670
MAIN1680
MAIN1690
MAIN1700
MAIN1710
MAIN1720
MAIN1730
MAIN1740
MAIN1750
MAIN1760
MAIN1770
MAIN1780
MAIN1790
MAIN1800
MAIN1810
MAIN1820
MAIN1830
MAIN1840
MAIN1850
MAIN1860
MAIN1870
MAIN1880
MAIN1890
MAIN1900
MAIN1910

```

400 LL=XXT(I)
410 IF (LL) 450,450,410
420 ENDPHA=STPHAS+XXT(I+1)
430 I=I+2
440 CALL RUN
450 IX=NUM+1
460 IF (XTABT(IX)) 420,420,440
470 WRITE (6,430)
480 FORMAT (IX44HTHE ABORT TIME IS ZERO,CHECK THE INPUT DATA.)
490 GO TO 1240
500 STPHAS=ENDPHA
510 N=NSS(LL)+1
520 GO TO 400

C STATISTICAL SUMMARY BEGINS HERE
C
450 NUM=NUM+1
460 IF (IFFEOP) 460,460,480
470 IFF=IFF+1
480 IF (T3) 470,480,470
490 CONTINUE
500 T3SUM=T3SUM+T3
510 T3=0.0
520 XTCUM=XTCUM+XCUM
530 UP4=UP4+ENDPHA-DNT2
540 JBB IS THE PHASE SEQUENCE NUMBER
550 IF (XTABT(NUM)-100000.) 500,490,500
560 X=ENDPHA
570 GO TO 510
580 X=XTABT(NUM)
590 X2=X*2
600 SUMX=SUMX+X
610 SUMX2=SUMX2+X2
620 IF (ISW(N)) 530,530,520
630 IAUP=IAUP+1
640 IF (NUM-INUM) 330,540,540
650 INUM=INUM+50
660 WRITE (6,560) NUM
670 FORMAT (/IX16HA GRAND TOTAL OF,16,24H MISSIONS HAVE BEEN RUN.)
680 XNUM=NUM
690 XPCAP=XTCUM/XNUM
700 WRITE (6,600) XPCAP
710 FORMAT (IX24HTHE RELIABILITY IS ,F8.4)
720 XPLCL=XPCAP-XK*SQRT(XPCAP*(1.-XPCAP)/XNUM)
730 IF (XPLCL) 620,630,630
740 XPLCL=0.0
750 WRITE (6,640) XPLCL
760 FORMAT (IX24HTHE LOWER CONF LIMIT IS ,F8.4)

```



```

650 WRITE (6,650) PL
    FORMAT (1X24HTHE SPEC REQUIREMENT IS ,F8.4)
660 WRITE (6,660) RED2
    FORMAT (1X17HTHE READINESS IS ,7XF8.4)
    AVA=UP4/TT3
670 WRITE (6,670) AVA
    FORMAT (1X28HTHE AVERAGE AVAILABILITY IS ,F8.4)
    XIAUP=IAUP
    AVAINS=XIAUP/XNUM
680 WRITE (6,680) AVAINS
    FORMAT (1X28HTHE INSTANT AVAILABILITY IS ,F8.4)
    XDWN=XNUM-XTCUM
    IF (XDWN) 690,690,700
690 XMTBA=2.0*SUMX
    XCLCA=0.434*SUMX
    VAR=(0.5*SUMX)**2
    GO TO 710
700 XMTBA=SUMX/XDWN
    VAR=(SUMX2/XNUM)-(SUMX/XNUM)**2
    CORR=(SUMX*(1/XDWN-1/XNUM))**2
    VAR=VAR+CORR
    XCLCA=XMTBA-(1.28*SQRT(VAR))
710 WRITE (6,720) XMTBA
720 FORMAT (1X41HTHE MEAN TIME BETWEEN MISSION FAILURES IS,F20.1)
730 WRITE (6,730) XCLCA
    FORMAT (1X21HTHE LCL,90, MTBMF IS ,F20.1)
740 WRITE (6,740) VAR
    FORMAT (1X27HTHE MTBMF VARIANCE IS ,F20.1)
    XIFF=IFF
    XIFR=IFR
    IF (IFF) 760,750,760
750 XMTUT=2.0*UP4
    XMDT=0.0
    GO TO 790
760 XMTUT=UP4/XIFF
    IF (IFR) 780,770,780
770 XMDT=(TT3-UP4-T3SUM)/XIFF
    GO TO 790
780 XMDT=(TT3-UP4-T3SUM)/XIFR
790 WRITE (6,810) XMTUT
800 WRITE (6,820) XMDT
810 FORMAT (1X18HTHE SYSTEM MUT IS ,F20.1)
820 FORMAT (1X18HTHE SYSTEM MDT IS ,F20.3)
830 IF (XPCAP-PL) 840,840,920
840 IF (NOPT-NUM) 870,870,850
850 WRITE (6,860)
860 FORMAT (1X14HANOOTHER SET OF ,3H 50,20HMISSIONS WILL BE RUN,43H TO
    1BTAIN REQUIRED STATISTICAL CONFIDENCE.)

```



```

870 GO TO 330
880 WRITE (6,880)
880 FORMAT (1X52HSIMULATION COMPLETE-OPTIMUM NUMBER MISSIONS WERE RUN)
890 IF (PL.EQ.1.) GO TO 910
890 WRITE (6,900)
900 FORMAT (1X33HWEAPON SYSTEM FAILS REQUIREMENTS.)
910 GO TO 1010
920 IF (NMAX-NUM) 930,930,960
930 WRITE (6,940)
940 FORMAT (1X52HSIM COMPLETE-PREDEFINED MAX NUMBER MISSIONS WERE RUN)
950 IF (XPLCL-PL) 890,990,990
960 IF (XPLCL-PL) 850,970,970
970 WRITE (6,980)
980 FORMAT (2X22HSIMULATION COMPLETE - )
990 IF (PL.EQ.1.) GO TO 1010
1000 WRITE (6,1000)
1010 FORMAT (1X33HWEAPON SYSTEM MEETS REQUIREMENTS.)
1010 CONTINUE
C*****READ CARD CONTAINING PRINTOUT OPTIONS
C*****SPRS=SPARES GIVES PRINTOUT OF AVG. SPARES USED PER MISSION
C*****APPLY EQUIPMENT TYPE
C*****APPL=APPL GIVES PRINTOUT OF CRITICAL EQUIPMENTS AND UNRELIABLE
C*****GAMMA=GAMMA GIVES PRINTOUT OF GAMMA FUNCTION WHICH REPRESENTS THE
C*****SYSTEM OR SUBSYSTEM CONFIGURATION AND VALUES AT TIME INTERVALS
C*****SPECIFIED ON PHASE CARD
IF (JCL-1) 1020,1020,1040
C1020 READ (5,1030) SPRS,APPL,GAMMA
C1020 READ (5,1030) SPRS,APPL,GAMMA,DMNO
C1030 FORMAT (3A4)
C1030 FORMAT (4A4)
C1040 IF (SPRS) 1050,1190,1050
C1040 IF (SPRS.EQ.BLNK) GO TO 1190
C
C EQUIP FAILURE AND CORRECTIVE MAINTENANCE SUMMARY
C
1050 IDIFF=0
1050 TAFM=0.0
1050 TACMMH=0.0
1050 WRITE (6,1060)
1060 FORMAT (1H1,4X53HEQUIP FAILURES AND CORRECTIVE MAINTENANCE(CM) SUMMARY)
1060 FMARY/8X71HEQUIP. NO. TYPE NO. TOTAL EQUIP. AVG. NO. FAILURES
2VGC. CM MANHOURS/32X8HFAILURES,7X11HPER MISSION,5X11HPER MISSION/)
DO 1090 I=1,NEQ
IF (XMTTR(IEQU(I)).EQ.9999.) GO TO 1090
IF (KEQU(I)) /XNUM
1070 AFM=KEQU(I)
1070 IEQ=IABS(IEQU(I))
1070 ACMMH=AFM*ABS(XMTTR(IEQ))

```

MAIN2400
 MAIN2410
 MAIN2420
 MAIN2430
 MAIN2440
 MAIN2450
 MAIN2460
 MAIN2470
 MAIN2480
 MAIN2490
 MAIN2500
 MAIN2510
 MAIN2520
 MAIN2530
 MAIN2540
 MAIN2550
 MAIN2560
 MAIN2570
 MAIN2580
 MAIN2590
 MAIN2600
 MAIN2610
 MAIN2620
 MAIN2630
 MAIN2640
 MAIN2650
 MAIN2660
 MAIN2670
 MAIN2680
 MAIN2690
 MAIN2700
 MAIN2710
 MAIN2720
 MAIN2730
 MAIN2740
 MAIN2750
 MAIN2760
 MAIN2770
 MAIN2780
 MAIN2790
 MAIN2800
 MAIN2810
 MAIN2820
 MAIN2830
 MAIN2840
 MAIN2850
 MAIN2860
 MAIN2870


```

1080  WRITE(6,1080) I,IEQ,KEQU(I),AFM,ACMMH
      FORMAT(10X I4,6X I10,6XF10.3,6XF10.3)
      IDIFF=IDIFF+KEQU(I)
      TAFM=TAFM+AFM
      TACMMH=TACMMH+ACMMH
1090  CONTINUE
      WRITE(6,1100) IDIFF,TAFM,TACMMH
1100  FORMAT(31X10H-----,6X10H-----/31X110,6X10H-----)
1110  CONTINUE
      WRITE(6,1120)
1120  FORMAT(1H1,3X41HAVERAGE NUMBER OF SPARES USED PER MISSION)
1130  WRITE(6,1130)
      FORMAT(/4X6HSPARES,7X4HSHIP,18X6HTENDER,16X4HBASE)
1140  WRITE(6,1140)
      FORMAT(8X4HTYPE,4X3(5HSTOCK,3X4HUSED,10X))
      DO 1170 J=1,NTYPE
      ALDONE=0.0
      DO 1150 I=1,3
      DONE(I)=I/USED(I,J)/XNUM
      ALDONE=ALDONE+DONE(I)
      CONTINUE
1150  IF(ALDONE) 1155,1170,1155
1155  WRITE(6,1160) J,{ISPARE(I,J),DONE(I),I=1,3}
1160  FORMAT(8X I4,4X3(15,F7.2,10X))
1170  CONTINUE
1180  CONTINUE
C1190  IF (APPL) 1200,1210,1200
1190  IF (APPL.EQ.BLNK) GO TO 1210
1200  BAPRIN=-1.0
      CALL APPLE
C
C
C
      SEE APPENDIX TO THESIS ON PROCEDURE TO ADD GAMMA AND DEMO
1210  CONTINUE
1220  CONTINUE
1230  CONTINUE
1240  STOP
      END

```



```

C      IF(ETIME(KEQ)+100001.001)55,120,55
C      IF(ETIME(KEQ)+99999.)60,60,120
C      IF(ETIFLAG(LL))120,70,120
C      IF A NEGATIVE ETIME IS PASSED TO TTE A TTF IS GENERATED. WE WANT
C      TO START REPAIR AT THE BEGINNING OF THE PHASE SO A POSITIVE ETIME
C      MUST BE PASSED.
C      ETIME(KEQ)=STPHAS
C      IABC=IABS(IEQU(KEQ))
C      IF (XMTTR(IABC)) 80,80,100
C      80 XXX=VMTTR(IABC,LL)
C      IF (XXX-9999.)120,90,120
C      90 ETIME(KEQ)=-99999.
C      GO TO 120
C      100 XXX=XMTTR(IABC)
C      110 CALL TTE
C      120 CONTINUE
C
C      II. TAG ALL EQUIPMENTS PREVIOUSLY FAILED OR OPERATING, NOT STANDBY.
C
C      DO 140 ILB=1,NEQ
C      KEQ=ILB
C      IEQU(KEQ)=IABS(IEQU(KEQ))
C      IF (ETIME(KEQ)-100000.)130,140,130
C      130 IEQU(KEQ)=-IABS(IEQU(KEQ))
C      140 CONTINUE
C      150 CONTINUE
C
C      III. FOR EQUIPMENTS USED IN CURRENT PHASE CONFIGURATION
C      A. THAT WERE USED IN PRIOR PHASE
C      1. IF EQUIPMENT IS UP, LEAVE AS IS
C      2. IF EQUIPMENT IS DOWN AND REPAIR IS ALLOWED, LEAVE AS
C      IS
C      3. IF EQUIPMENT IS DOWN AND REPAIR IS DISALLOWED, ADD
C      CURRENT PHASE DURATION
C      B. THAT WERE NOT USED IN PRIOR PHASE
C      1. IF EQUIPMENT IS DOWN AND REPAIR IS ALLOWED, LEAVE AS
C      IS
C      2. IF EQUIPMENT IS DOWN AND REPAIR IS DISALLOWED, ADD
C      CURRENT PHASE DURATION
C      3. OTHERWISE, GENERATE TTF
C
C      KKK2=KKK
C      K=NLIN(LLL)
C      DO 250 I=1,K
C      DO 250 J=2,8
C      KEQ=IABS(I8(LL,I,J))
C      IF (KEQ-MAXNEQ)151,151,250
C      151 IF(KEQ)250,250,155

```



```

155 IF(ETIME(KEQ)+100001.001)160,250,160
160 IEQU(KEQ)=IABS(IEQU(KEQ))
    IABC=IEQU(KEQ)
170 IF (XMTTR(IABC)) 170,170,180
180 IF (VMTTR(IABC,LL)-9999.) 180,190,180
    CONTINUE
190 IF (IFLAG(LL)-1) 210,190,210
    IF (ETIME(KEQ)) 200,210,210
200 ETIME(KEQ)=ETIME(KEQ)-(ENDPHA-STPHAS)
210 IF (ETIME(KEQ)-10000.) 220,240,220
220 IF (ABS(ETIME(KEQ))-STPHAS) 240,230,230
230 IF (STPHAS) 250,240,250
240 ETIME(KEQ)=-STPHAS
    IABC=IABS(IEQU(KEQ))
    XXX=XMTBF(IABC)
    CALL TTE
250 CONTINUE
    KKK2=1

```

IV. FOR EQUIPMENTS NOT IN CURRENT PHASE CONFIGURATION

- A. IF EQUIPMENT IS UP, PUT IN STANDBY.
 B. IF EQUIPMENT IS DOWN
 1. IF REPAIR IS ALLOWED, LEAVE AS IS.
 2. IF REPAIR IS DISALLOWED, ADD DURATION OF CURRENT PHASE

```

DQ 330 ILB=1,NEQ
KEQ=ILB
255 IF(ETIME(KEQ)+100001.001)255,330,255
260 IF(IEQU(KEQ))260,260,330
    IEQU(KEQ)=IABS(IEQU(KEQ))
    IABC=IEQU(KEQ)
270 IF (XMTTR(IABC)) 270,270,280
280 IF (VMTTR(IABC,LL)-9999.) 280,290,280
    CONTINUE
290 IF (IFLAG(LL)-1) 310,290,310
    IF (ETIME(KEQ)) 300,320,320
300 ETIME(KEQ)=ETIME(KEQ)-(ENDPHA-STPHAS)
    GO TO 330
EQUIPMENTS THAT WERE DOWN AT THE BEGINNING OF A PHASE IN WHICH
THEY WERE NOT USED, WERE NOT PUT IN STANDBY AFTER REPAIR. INSTEAD
THEY WERE ALLOWED TO FAIL AGAIN IN THAT PHASE.
310 IF(ETIME(KEQ)) 331,320,320
320 ETIME(KEQ)=10000.
    IEQU(KEQ)=IABS(IEQU(KEQ))
    GO TO 330
331 IEQU(KEQ)=-IABS(IEQU(KEQ))
330 CONTINUE

```

V. SET STANDBY EQUIPMENTS ETIME TO 100000.

```

RUN 0970
RUN 0980
RUN 0990
RUN 1000
RUN 1010
RUN 1020
RUN 1030
RUN 1040
RUN 1050
RUN 1060
RUN 1070
RUN 1080
RUN 1090
RUN 1100
RUN 1110
RUN 1120
RUN 1130
RUN 1140
RUN 1150
RUN 1160
RUN 1170
RUN 1180
RUN 1190
RUN 1200
RUN 1210
RUN 1220
RUN 1230
RUN 1240
RUN 1250
RUN 1260
RUN 1270
RUN 1280
RUN 1290
RUN 1300
RUN 1310
RUN 1320
RUN 1330
RUN 1340
RUN 1350
RUN 1360
RUN 1370
RUN 1380
RUN 1390
RUN 1400
RUN 1410
RUN 1420
RUN 1430
RUN 1440

```



```

C          CALL STATUS
C          CALL STNDBY
C          CALCULATIONS FOR INSTANT AVA AT START OF PHASE.
C          CALL STATUS
C          IF (ISW(N)) 350,350,340
340  IAUPI(JBB)=IAUPI(JBB)+1
350  XIAUPI=IAUPI(JBB)
C          XAVI=XIAUPI/XKAA
C          DNTI IS TOTAL SYSTEM DOWNTIME IN PHASE.
C          TIME=STPHAS
C          DNTI=0.0
C          DO 360 KSS=1,N
360  SSTIME(LL,KSS,1)=0.0
C          THE ACTUAL MISSION SIMULATION BEGINS HERE
C          TP=TIME
370  CALL STNDBY 390,440,390
380  IF (KS(6)) 390,440,390
390  WRITE (6,430) TP
C          DO 410 J=1,NEQ
400  IEQ=IABS(IEQU(J)) 400,410,400
410  WRITE(6,420) J,IEQ,ETIME(J)
420  CONTINUE
430  FORMAT (1X15,1X15,5XF22.4)
440  CALL EVENT
C          TIME=ABS(ETIME(KEQ))
450  IF (KS(5)) 450,470,450
460  WRITE (6,460) KEQ,ETIME(KEQ),KAA
470  FORMAT (10X5HEQUIP,15,F12.4,5X7HMISSION,110)
C          DELT=TIME-TP
C          CALL STATUS
C          SET TIME CLOCKS
C          DO 510 KSS=1,NX
480  IF (ISW(KSS)) 490,490,500
490  SSTIME(LL,KSS,1)=SSTIME(LL,KSS,1)+DELT
C          GO TO 510
500  SSTIME(LL,KSS,1)=0.0
510  CONTINUE
C          IF (ISW(N)) 520,520,530
520  SSTIME(LL,N,1)=SSTIME(LL,N,1)+DELT

```


RUN 1930
 RUN 1940
 RUN 1950
 RUN 1960
 RUN 1970
 RUN 1980
 RUN 1990
 RUN 2000
 RUN 2010
 RUN 2020
 RUN 2030
 RUN 2040
 RUN 2050
 RUN 2060
 RUN 2070
 RUN 2080
 RUN 2090
 RUN 2100
 RUN 2110
 RUN 2120
 RUN 2130
 RUN 2140
 RUN 2150
 RUN 2160
 RUN 2170
 RUN 2180
 RUN 2190
 RUN 2200
 RUN 2210
 RUN 2220
 RUN 2230
 RUN 2240
 RUN 2250
 RUN 2260
 RUN 2270
 RUN 2280
 RUN 2290
 RUN 2300
 RUN 2310
 RUN 2320
 RUN 2330
 RUN 2340
 RUN 2350
 RUN 2360
 RUN 2370
 RUN 2380
 RUN 2390
 RUN 2400

```

T3=T3+DELT
IF (TIME-ENDPHA) 522,522,521
521 T3=T3+ENDPHA-TP-DELT
522 RDT=ROD+DELT
GO TO 550
530 T3=0.0
RDT=0.0
IF (SSTIME(LL,N,1)) 1140,550,540
540 T1=SSTIME(LL,N,1)
SSTIME(LL,N,1)=0.0
550 CONTINUE

C      SYSTEM FAILURE AND REPAIR TALLY
C
C      IF (SSTIME(LL,N,1)) 570,560,570
560 IF (T1) 620,620,580
570 IF (T1) 620,610,620
580 IFF=IFF+1
590 IFR=IFR+1
600 T1=0.0
GO TO 620
610 T1=SSTIME(LL,N,1)
620 CONTINUE

C CHECK IF ANY DOWN TIMES HAVE EXCEEDED CRITERIA
C
C      IF(ICRI) 640,640,660
C
C      TAD2 - MISSION ALLOWABLE DOWNTIME
C
640 ISSC=1
ISSA(1)=N
IF(RDT-TAD2)645,645,930
645 ICRI=0
650 IF(SSTIME(LL,N,1)-SSTIME(LL,N,2)) 650,650,960
ICRI=0
ISSC=0
DO 655 KSS=1,NX
IF(SSTIME(LL,KSS,1)-SSTIME(LL,KSS,2))655,655,652
652 ISSC=ISSC+1
655 ISSA(ISSC)=KSS
CONTINUE
IF(ISSC)660,660,962
660 CONTINUE

C CHECK IF TIME GREATER THAN END OF PHASE
C
C      IF (TIME-ENDPHA) 670,670,1140
  
```



```

C IFLAG = 0 INDICATES REPAIR IS ALLOWED DURING PHASE.
C REPOL IS THE PROBABILITY THAT A REPAIR IS PERFORMED.
C
670 IF (ISW(N)) 680,680,730
680 CALL APPLE
730 IF (ETIME(KEQ)) 810,810,740
740 IABC=IABS(IEQU(KEQ))
750 IF (IFLAG(LL)-1) 750,760,750
750 CALL RANDOM(ISEED,RN,1)
760 IF (RN-REPOL) 770,770,800
760 ETIME(KEQ)=-99999.
770 GO TO 830
770 IF (XMTTR(IABC)) 780,780,790
780 XXX=VMTTR(IABC,LL)
790 IF (XXX-9999.) 820,760,820
790 XXX=XMTTR(IABC)
800 GO TO 820
800 ETIME(KEQ)=-100001.001
810 GO TO 830
810 IABC=IABS(IEQU(KEQ))
820 XXX=XMTBF(IABC)
820 IF (IEQU(KEQ)) 811,821,821
811 IEQU(KEQ)=IABS(IEQU(KEQ))
811 ETIME(KEQ)=100000.
820 GO TO 830
821 CALL TTE
830 IF (ETIME(KEQ)) 840,1150,870
C EVENT WAS FAILURE
C
840 KEQU(KEQ)=KEQU(KEQ)+1
840 IF (ISW(N)) 850,850,370
850 ONT1=ONT1+DELT
850 IF (ICRI) 860,370,860
860 REDAD1(JBB)=REDAD1(JBB)+DELT
860 GO TO 370
C EVENT WAS REPAIR
C
870 CONTINUE
870 IF (ISW(N)) 880,880,370
880 ONT1=ONT1+DELT
880 IF (ICRI) 890,900,890
890 REDAD1(JBB)=REDAD1(JBB)+DELT
900 TDOWN=TIME-SS TIME(LL,N,1)
900 TTEMP=SS TIME(LL,N,1)
900 IF (KS(13)) 370,370,910

```

```

RUN 2410
RUN 2420
RUN 2430
RUN 2440
RUN 2450
RUN 2460
RUN 2470
RUN 2480
RUN 2490
RUN 2500
RUN 2510
RUN 2520
RUN 2530
RUN 2540
RUN 2550
RUN 2560
RUN 2570
RUN 2580
RUN 2590
RUN 2600
RUN 2610
RUN 2620
RUN 2630
RUN 2640
RUN 2650
RUN 2660
RUN 2670
RUN 2680
RUN 2690
RUN 2700
RUN 2710
RUN 2720
RUN 2730
RUN 2740
RUN 2750
RUN 2760
RUN 2770
RUN 2780
RUN 2790
RUN 2800
RUN 2810
RUN 2820
RUN 2830
RUN 2840
RUN 2850
RUN 2860
RUN 2870
RUN 2880

```



```

910 WRITE (6,920) LL,TDOWN,TTEMP,KAA      RUN 2890
920 FORMAT (13H DURING PHASE,I6,20HSYSTEM WENT DOWN AT ,F14.4,13H DOWN      RUN 2900
1 TIME IS ,F14.4,3X7HMISSION,I6)          RUN 2910
GO TO 370                                  RUN 2920
C ABORT PROCEDURE                          RUN 2930
C                                           RUN 2940
C                                           RUN 2950
930 ICRI=5                                  RUN 2960
TABORT=TIME-(RDT-TAD2)                     RUN 2970
IF (TABORT-ENDPHA)940,645,645              RUN 2980
940 IF (XTABT(KAA)-100000.) 660,950,660    RUN 2990
950 ITEMP=1                                 RUN 3000
ITEMP2=1                                    RUN 3010
WRITE(6,1010)LL,JBB,KAA,TABORT,TITLE(LL,N),TAD2 RUN 3020
GO TO 1020                                  RUN 3030
960 ICRI=4                                  RUN 3040
GO TO 964                                   RUN 3050
962 ICRI=2                                  RUN 3060
964 TABORT=TIME-(SSTIME(LL,ISSA(1),1)-SSTIME(LL,ISSA(1),2)) RUN 3070
970 IF (TABORT-ENDPHA) 990,980,980          RUN 3080
980 IF (ICRI-2)650,985,650                 RUN 3090
985 ICRI=0                                  RUN 3100
GO TO 660                                   RUN 3110
990 IF (XTABT(KAA)-100000.) 660,1000,660    RUN 3120
1000 ITEMP=1                                RUN 3130
ITEMP2=1                                    RUN 3140
DO 1005 I=1,ISSC                           RUN 3150
1005 WRITE(6,1009)LL,JBB,KAA,TABORT,TITLE(LL,ISSA(I)) RUN 3160
1 SSTIME(LL,ISSA(I),2)                     RUN 3170
1009 FORMAT(1X9HIN PHASE ,I2,1X3HSEQ,I3,4X7HMISSION,I6,4X15HABORTED AT RUN 3180
1 TIME,F10.4,10H BECAUSE ,A4,35H EXCEEDED PHASE ALLOWABLE DOWNTIME RUN 3190
2,2XF10.3,5H HRS.)                        RUN 3200
1010 FORMAT (1X9HIN PHASE ,I2,1X3HSEQ,I3,4X7HMISSION,I6,4X15HABORTED AT RUN 3210
1 TIME,F10.4,10H BECAUSE ,A4,37H EXCEEDED MISSION ALLOWABLE DOWNTIME RUN 3220
2 TIME,2XF10.3,5H HRS.)                   RUN 3230
1020 XTABT(KAA)=TABORT                     RUN 3240
IF (TABORT) 1590,1590,1040                 RUN 3250
1040 DO 1110 I=1,NEQ                       RUN 3260
IF (ETIME(I)) 1050,1110,1110              RUN 3270
1050 IF (IEQU(I)) 1080,1110,1080           RUN 3280
1080 IF (KS(2)) 1090,1110,1090            RUN 3290
1090 WRITE (6,1100) I,ETIME(I)            RUN 3300
1100 FORMAT (17X9HEQUIPMENT,I5,24H DOWN IT WILL COME UP AT,F16.4) RUN 3310
1110 CONTINUE                              RUN 3320
1120 CALL APPE                              RUN 3330
ITEMP2=0                                    RUN 3340
1130 GO TO 660                              RUN 3350
C                                           RUN 3360

```



```

C END OF PHASE PROCEDURE
C TDEOP IS TIME DOWN AT END OF PHASE
C DNT2 IS TOTAL SYSTEM DOWNTIME IN MISSION. DUE TO ABORT
C AENDT1 IS DOWNTIME IN REMAINDER OF PHASE (UP TO CURRENT PHASE)
C AENDT2 IS DOWNTIME IN MISSION DUE TO ABORT (UP TO CURRENT PHASE)
C REDAD1 IS ADJUSTMENT TIME FOR REDNESS CALCULATION IN PHASE
C REDAD2 IS ADJUSTMENT TIME FOR REDNESS CALCULATION IN MISSION
C
1140 CONTINUE
    IF FEOP=ISW(N)
    IF (ISW(N)) 1160,1160,1270
1150 CONTINUE
1160 TDEOP=ENDPHA-TP
1170 CONTINUE
    IF (KS(3)) 1210,1210,1180
1180 IF (TDEOP) 1190,1210,1190
1190 WRITE (6,1200) LL,TDEOP,KAA
1200 FORMAT (1X27HSYSTEM DOWN AT END OF PHASE,16,13H FOR DURATION,F10.4)
1210 CONTINUE
    DNT1=DNT1+TDEOP
    RDT=RDT+TDEOP-DELT
    DELT=TDEOP
    CALL APPLE
1270 CONTINUE
    IF (ICRI) 1280,1290,1280
1280 REDAD1(JBB)=REDAD1(JBB)+TDEOP
1290 DNT2=DNT2+DNT1
1300 IF (DNT2) 1310,1330,1310
1310 IF (KS(6)) 1325,1330,1325
1325 WRITE(6,1320) LL,KAA,DNT2
1320 FORMAT (1X5HPHASE,15,1X29HTOTAL SYS DOWNTIME IN MISSION,15,1X3HWA SRUN
1, F12.4, 4H HRS)
1330 CONTINUE
C
C COMPUTE RELIABILITY FOR EACH PHASE *****
C JBB IS THE PHASE SEQUENCE NUMBER *****
C
    IF (ICRI) 1350,1350,1340
    IF (ITEMP) 1360,1360,1350
1340 XCUM=1-ITEMP
1350 INOABT(JBB)=INOABT(JBB)+1-ITEMP
    INMI(JBB)=INMI(JBB)+1
1360 CONTINUE
    XNO=INOABT(JBB)
    TNMI=INMI(JBB)
    IF (TNMI) 1380,1380,1370
1370 RELY=XNO/TNMI

```

```

RUN 3370
RUN 3380
RUN 3390
RUN 3400
RUN 3410
RUN 3420
RUN 3430
RUN 3440
RUN 3450
RUN 3460
RUN 3470
RUN 3480
RUN 3490
RUN 3500
RUN 3510
RUN 3520
RUN 3530
RUN 3540
RUN 3550
RUN 3560
RUN 3570
RUN 3580
RUN 3590
RUN 3600
RUN 3610
RUN 3620
RUN 3630
RUN 3640
RUN 3650
RUN 3660
RUN 3670
RUN 3680
RUN 3690
RUN 3700
RUN 3710
RUN 3720
RUN 3730
RUN 3740
RUN 3750
RUN 3760
RUN 3770
RUN 3780
RUN 3790
RUN 3800
RUN 3810
RUN 3820
RUN 3830
RUN 3840

```



```

1380 GO TO 1390
1380 RELY=0.0
1390 RELPY=RELPY*RELY
1390 TT1=ENDPHA-STPHAS
1390 TT2(JBB)=TT2(JBB)+TT1
1390 UP1=TT1-DNT1
1390 UP2(JBB)=UP2(JBB)+UP1
1390 IF (ISW(N)) 1410,1410,1400
1400 I AUP2(JBB)=IAUP2(JBB)+1
1410 XIAUPP=IAUP2(JBB)
1410 XAV=XIAUPP/XKAA
1420 IF (KAA-INUM) 1570,1420,1570
1420 WRITE (6,1430) XAV
1430 FORMAT (/47X20HINSTANT AVAILABILITY,5X2X4H IS ,F6.4)
1440 WRITE (6,1450) LL,JBB,RELY,LL,RELPY
1450 FORMAT (9X17HRELIABILITY PHASE,I3,1H,,I3,5H, IS ,F6.4,3X25HRELIABILITY UP TO PHASE ,I2,4H IS ,F6.4)
1450 LLITY UP TO PHASE
1450 RELGA(JBB)=RELPY
1450 AENDT1=0.0
1450 AENDT2=0.0
1460 DO 1520 I=1,KAA
1470 IF (XTABT(I))-100000. 1470,1520,1520
1470 IF (XTABT(I))-TIMA(JBB)) 1480,1520,1520
1480 AENDT2=AENDT2+TIMA(JBB)-XTABT(I)
1480 JBB1=JBB-1
1490 IF (JBB1) 1500,1500,1490
1490 IF (TIMA(JBB1)-XTABT(I)) 1500,1500,1510
1500 AENDT1=AENDT1+TIMA(JBB)-XTABT(I)
1510 GO TO 1520
1510 AENDT1=AENDT1+TIMA(JBB)-TIMA(JBB1)
1520 CONTINUE
1520 TT3=TT3+TT2(JBB)
1520 UP3=UP3+UP2(JBB)
1520 REDAD2=REDAD2+REDAD1(JBB)
1520 RED1=(UP2(JBB)-AENDT1+REDAD1(JBB))/TT2(JBB)
1520 RED2=(UP3-AENDT2+REDAD2)/TT3
1530 WRITE (6,1540) RED1,RED2
1540 FORMAT (9X16HREADINESS ,9X4H IS ,F6.4,3X25HREADINESS ,2X4H IS ,F6.4)
1540 AVAL=UP2(JBB)/TT3
1540 AVA2=UP3/TT3
1550 WRITE (6,1550) AVAL,AVA2
1550 FORMAT (9X23H AVERAGE AVAILABILITY ,2X4H IS ,F6.4)
1550 IAILABILITY
1560 WRITE (6,1560) XAV
1560 FORMAT (47X20HINSTANT AVAILABILITY,5X2X4H IS ,F6.4)
1570 CONTINUE
1580 KKK=1

```


JBB=JBB+1
T1=SSTIME(LL,N,1)
1590 RETURN
END

RUN 4330
RUN 4340
RUN 4350
RUN 4360


```

SUBROUTINE PACK
COMMON /ALPHA/DNT2,ENDPHA,ICRI,IFF,IFR,INUM,IQPT,JBB,KEQ,KKK,KZZ
1,KKI,KS1,LL,LLLAST,NEQ,NPH,NTYPE,NUM,READAD2,REDAD1(100),RELP,RED2
2,RELPLY,RETA/NRD(6,300),IB(6,300,8),NLINE(6)
COMMON/EXTRA/ KS(20),ISW(31)
COMMON /N/IEQU(500),KEQU(500),ETIME(1000),XMTBF(200),XMTTR(200)
COMMON/NPH/ NSS(6),IFLAG(6),TITLE(6,31),SSTIME(6,31,2),ISS(6,31)
COMMON /TYP/EX(2,200),ISPARE(3,200),IUSED(3,200),IUSED(3,200)
COMMON /MAX/MAXNEQ,MAXTYP,MAXIB,MAXSID
COMMON/VDC/VDC(50,6),IUI(200),VMTTR(200,6),TAD2
COMMON /PACKAP/ IBNUM( 6, 500),ISYS( 6),F(200,4)
COMMON/STAN/ISTB(60,10,6)
COMMON /CSPARE/ SPRI,SPR2,SPR3,SPR4,SPR5,SPR6,SPR7,SPR8,SPR9
1,SPRI0,SPRI1,SPRI2,SPRI3,SPRI4,ITMPQP(200)
DIMENSION LOAD(19)
DIMENSION DUM(4)
DIMENSION IVAL(10)
DATA IBLANK/4H /
C
C KOPT OBTAINS ONE OF SUNDRY COMBINATIONS OF SWITCHES
C KOPT=1 GIVES MANAGEMENT SUMMARY PRINTOUT
C KOPT=2 GIVES ENGINEERING SUMMARY PRINTOUT
C KOPT=3 GIVES ENGINEERING DETAILS PRINTOUT
C KOPT=4 INPUTS SUPPRESSED ON OUTPUT PRINTOUT
C KOPT=5 DESIGN YOUR OWN OUTPUT PRINTOUT
C
C READ (5,10) KOPT,(KS(I),I=1,13)
C WRITE (6,20) KOPT,(KS(I),I=1,13)
C 10 FORMAT (20I4)
C 20 FORMAT (1H1,110,5X19I4)
C
C IFLAG = 0 INDICATES REPAIR IS ALLOWED DURING PHASE.
C
C READ (5,10) (IFLAG(I),I=1,NPH)
C WRITE (6,30) (IFLAG(I),I=1,NPH)
C 30 FORMAT (10I4)
C
C REPOL IS THE PROBABILITY THAT A REPAIR IS PERFORMED.
C
C READ(5,40) REPOL,TAD2,XM,XM1
C 40 FORMAT(F4.0,F8.0,2F4.0)
C 50 FORMAT(20F4.0)
C IF(XM) 35,35,55
C 35 XM=1.0
C 55 IF(XM1) 36,36,56
C 36 XM1=1.
C 56 WRITE(6,60) REPOL,TAD2,XM,XM1

```

```

PACK0010
PACK0020
PACK0030
PACK0040
PACK0050
PACK0060
PACK0070
PACK0080
PACK0090
PACK0100
PACK0110
PACK0120
PACK0130
PACK0140
PACK0150
PACK0160
PACK0170
PACK0180
PACK0190
PACK0200
PACK0210
PACK0220
PACK0230
PACK0240
PACK0250
PACK0260
PACK0270
PACK0280
PACK0290
PACK0300
PACK0310
PACK0320
PACK0330
PACK0340
PACK0350
PACK0360
PACK0370
PACK0380
PACK0390
PACK0400
PACK0410
PACK0420
PACK0430
PACK0440
PACK0450
PACK0460
PACK0470
PACK0480

```



```

60 FORMAT(1X,4F10.2)
GO TO (70,90,100,120,130),KOPT
C KS SWITCHES ARE ON WHEN SET=1
C OFF
C
70 KS(1)=1
KS(4)=0
80 KS(3)=0
KS(2)=0
KS(2)=1
KS(5)=0
KS(6)=0
KS(7)=0
KS(8)=0
KS(9)=0
KS(10)=0
GO TO 130
90 KS(1)=1
KS(6)=0
KS(10)=0
GO TO 110
100 KS(1)=1
KS(6)=1
KS(7)=1
KS(10)=1
KS(12)=1
110 KS(2)=1
KS(3)=1
KS(4)=1
KS(5)=1
KS(7)=0
KS(8)=1
KS(9)=1
GO TO 130
120 KS(1)=0
KS(4)=0
GO TO 80
C
C C C
C FILL EQUIPMENT AND TYPE TABLES
C
130 NEQ=0
DO 140 I=1,MAXNEQ
ETIME(I)=100000.
IEQU(I)=0
140 CONTINUE
DO 155 J=1,6
DO 150 I=1,MAXTYP

```

```

PACK0490
PACK0500
PACK0510
PACK0520
PACK0530
PACK0540
PACK0550
PACK0560
PACK0570
PACK0580
PACK0590
PACK0600
PACK0610
PACK0620
PACK0630
PACK0640
PACK0650
PACK0660
PACK0670
PACK0680
PACK0690
PACK0700
PACK0710
PACK0720
PACK0730
PACK0740
PACK0750
PACK0760
PACK0770
PACK0780
PACK0790
PACK0800
PACK0810
PACK0820
PACK0830
PACK0840
PACK0850
PACK0860
PACK0870
PACK0880
PACK0890
PACK0900
PACK0910
PACK0920
PACK0930
PACK0940
PACK0950
PACK0960

```



```

C
C
C READ TYPE CARDS
150 XMTBF(I)=0.0
155 VMITR(I,J)=0.0
155 XMTTR(I)=0.0
155 CONTINUE
160 WRITE (6,170)
170 FORMAT (/11H TYPE NAME,18X4HMTBF,5X4HMTTR,7X2HDC,8X4HADT1,4X4HADT2)
180 READ (5,190) I,(DUM(J),J=1,4),X,Y,U,V,W,IDUM
190 FORMAT (14,4A4,F8.0,4F4.0,I4)
200 IF (I-MAXTYP) 220,220,210
210 WRITE (6,440)
220 GO TO 1000
220 DO 230 J=1,4
230 F(I,J)=DUM(J)
240 IF (IUI(I)) 240,250,240
240 READ (5,450) IU,(VDC(IU,ILL),ILL=1,NPH)
250 IF (Y) 260,280,280
260 READ (5,50) (VMITR(I,J),J=1,NPH)
270 IF (I) 280,490,280
280 EX(1,I)=V
290 IF (KS(1)) 310,310,290
290 WRITE (6,300) I,(F(I,J),J=1,4),X,Y,U,V,W
300 FORMAT (1X14,2X4A4,2XF10.1,F10.2,F10.3,2(F8.1))
310 IF (IUI(I)) 380,380,320
320 IF (KS(1)) 340,340,330
330 WRITE (6,460) (VDC(IU,ILL),ILL=1,NPH)
340 DO 370 ILL=1,NPH
350 IF (VDC(IU,ILL)) 360,360,350
350 VDC(IU,ILL)=(X/VDC(IU,ILL))*XM
360 GO TO 370
360 VDC(IU,ILL)=(X/.0001)*XM
370 CONTINUE
380 IF (KS(1)) 410,410,390
390 IF (Y) 400,410,410
400 WRITE (6,470) (VMITR(I,J),J=1,NPH)
410 IF (XMTBF(I)) 420,430,420
420 WRITE (6,480) I
430 GO TO 1000
430 IF (U) 435,435,433
433 XMTBF(I)=XM*(X/U)
435 XMTTR(I)=Y*XM1
435 GO TO 180

```



```

440 FORMAT (9X39HEQUIP TYPES HAVE EXCEEDED MAX ALLOWABLE)
450 FORMAT (I4,19(F4.0))
460 FORMAT (14X16HVARY DUTY CYCLE ,4F10.3)
470 FORMAT (14X16HVARIABLE MTTR ,4F10.3)
480 FORMAT (1X4HTYPE,15,1X13HDEFINED TWICE)

C
C AFTER LAST TYPE CARD MUST BE A BLANK CARD, THEN FOLLOWS EQU CARDS.
C

490 WRITE (6,500)
500 FORMAT (/1X15HTYPE EQUIPMENT)
510 READ (5,10) NTYPE,(LOAD(I),I=1,19)
520 IF (LOAD(1)) 520,650,520
520 DO 620 I=1,19
530 IF (LOAD(I)) 530,620,530
530 IBM=LOAD(I)
540 IF (IBM-500) 560,560,540
540 WRITE (6,550)
550 FORMAT(55H EQUIPMENT NUMBER GREATER THAN 500 *****))
560 GO TO 1000
560 IF (IBM-NEQ) 580,580,570
570 NEQ=IBM
580 IF (IEQU(IBM)) 590,610,590
590 WRITE (6,600) IBM
590 GO TO 1000
600 FORMAT (1X9HEQUIPMENT,15,1X34HDEFINED TWICE *****))
610 CONTINUE
620 IEQU(IBM)=NTYPE
620 CONTINUE
630 IF (KS(1)) 640,640,630
630 WRITE (6,10) NTYPE,(LOAD(I),I=1,19)
640 NTV=NTYPE
640 GO TO 510

C
C ALL EQUIPMENT & TYPE CARDS HAVE BEEN READ IN.
C THE LAST CARD AT THIS POINT MUST BE A BLANK CARD.
C

650 WRITE (6,660)
660 FORMAT(/1X11HSPARES TYPE,6X4HSHIP,4X6HTENDER,6X4HBASE,12X6HFACOR)
660 DO 670 I=1,3
NTYPE=NTY
DO 670 J=1,NTYPE
670 IUSED(I,J)=0
READ(5,675) IUNLIM,SX,SPR1,SPR2,SPR3,SPR4,SPR5,SPR6,SPR7,SPR8,SPR9
1,SPR10,SPR11,SPR12,SPR13,SPR14
675 1,SPR10,SPR11,SPR12,SPR13,SPR14
675 IF (SX-999.) 681,676,681
676 CALL SPARES
IF(KS(1)) 740,740,677

```

PACK1450
 PACK1460
 PACK1470
 PACK1480
 PACK1490
 PACK1500
 PACK1510
 PACK1520
 PACK1530
 PACK1540
 PACK1550
 PACK1560
 PACK1570
 PACK1580
 PACK1590
 PACK1600
 PACK1610
 PACK1620
 PACK1630
 PACK1640
 PACK1650
 PACK1660
 PACK1670
 PACK1680
 PACK1690
 PACK1700
 PACK1710
 PACK1720
 PACK1730
 PACK1740
 PACK1750
 PACK1760
 PACK1770
 PACK1780
 PACK1790
 PACK1800
 PACK1810
 PACK1820
 PACK1830
 PACK1840
 PACK1850
 PACK1860
 PACK1870
 PACK1880
 PACK1890
 PACK1900
 PACK1910
 PACK1920


```

677 DO 678 I=1, NTYPE
678 WRITE(6,750) I, (ISPARE(J,I), J=1,3), SX
679 GO TO 740
681 IF(SX) 684, 682, 684
682 SX=1.0
684 IF(IUNL IM-IBLANK) 690, 720, 690
690 WRITE(6,700)
700 FORMAT (1X41HALL EQUIPMENT TYPES HAVE UNLIMITED SPARES)
DO 710 I=1, NTYPE
DO 710 J=1, 3
710 ISPARE(J,I)=90000
720 GO TO 760
DO 740 I=1, NTYPE
740 READ(5,10) (ISPARE(J,I), J=1,3)
BILL=FLOAT( ISPARE(1,I))*SX
IF(INT(BILL)-BILL) 727, 725, 727
725 ISPARE(1,I)=BILL
GO TO 728
727 ISPARE(1,I)=INT(BILL)+1
728 CONTINUE
IF (KS(1)) 740, 740, 730
730 WRITE(6,750) I, (ISPARE(J,I), J=1,3), SX
740 CONTINUE
750 FORMAT(5X, I4, 2X, 3I10, 13X, F6.2)

C
760 WRITE(6,770) NPH
770 FORMAT (1H1, 3X28HTHE MISSION WILL BE RUN WITH, I4, 7H PHASE , 27HTYPE
1S IN VARIABLE SEQUENCE.)

C
C PHASE CARDS APPEAR NEXT.
C
DO 777 I=1, 6
DO 776 J=1, 10
DO 775 K=1, 60
ISTB(K, J, I)=0
775 CONTINUE
776 CONTINUE
777 CONTINUE
DO 990 K=1, NPH
READ(5,780) XID, LL, NSS(K), ISS(K, NSS(K)+1), SSTIME(K, NSS(K)+1, 2)
ISS(K)=ISS(K, NSS(K)+1)
780 FORMAT (A4, 3I4, F8.0)
NX=NSS(K)
NX+1
IF (KS(1)) 820, 820, 790
790 WRITE(6,810) XID, LL, NSS(K), ISS(K, N), SSTIME(K, N, 2)
800 FORMAT (1X44, 3I4, F10.2)
810 FORMAT (/1XA4, 3I4, F10.2)

```

PACK1930
 PACK1940
 PACK1950
 PACK1960
 PACK1970
 PACK1980
 PACK1990
 PACK2000
 PACK2010
 PACK2020
 PACK2030
 PACK2040
 PACK2050
 PACK2060
 PACK2070
 PACK2080
 PACK2090
 PACK2100
 PACK2110
 PACK2120
 PACK2130
 PACK2140
 PACK2150
 PACK2160
 PACK2170
 PACK2180
 PACK2190
 PACK2200
 PACK2210
 PACK2220
 PACK2230
 PACK2240
 PACK2250
 PACK2260
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 PACK2280
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 PACK2400

PACK2410
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PACK2500
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PACK2670
PACK2680
PACK2690
PACK2700
PACK2710
PACK2720
PACK2730
PACK2740
PACK2750
PACK2760
PACK2770
PACK2780
PACK2790
PACK2800
PACK2810
PACK2820
PACK2830
PACK2840
PACK2850
PACK2860
PACK2870
PACK2880

```

820 TITLE(K,N)=XI
DO 840 IK=1,NX
  READ (5,780) TITLE(K,IK),KK,MM,ISS(K,IK),SSTIME(K,IK,2)
  IF (KS(1)) 840,840,830
830 WRITE (6,800) TITLE(K,IK),LL,MM,ISS(K,IK),SSTIME(K,IK,2)
840 CONTINUE

C EQUIPMENT & GROUP CONFIGURATION MATRIX
C
      DO 850 JA=1,MAXIB
      DO 850 JB=1,8
        IB(K,JA,JB)=0
        NRO(K,JA)=0
850 CONTINUE
      IOR=0
      I=0
      I=I+1
      READ(5,10) (IVAL(J),J=1,10),IRULE
      IF(IVAL(1).EQ.0) GO TO 990
      IF(IRULE.NE.0)GO TO 930
      IF(IRULE.NE.0)GO TO 930
C** GROUP CARD. CHECK IF MORE THAN ALLOWED.
      IF(I.LE.MAXIB) GO TO 880
      WRITE(6,870) MAXIB
870 FORMAT(1H1,10X,29H# OF GROUP CARDS GREATER THAN,I4)
      STOP
880 NRO(K,I)=IVAL(1)
      DO 890 J=1,8
        IB(K,I,J)=IVAL(J+1)
890 CONTINUE
      IBNUM(K,IB(K,I,1)-500)=I
      NLINE(K)=I
      IF(KS(1)) 860,860,910
910 WRITE(6,920) NRO(K,I),(IB(K,I,J),J=1,8)
920 FORMAT(1X,13,8I4)
      GO TO 860
930 CONTINUE
      I=I-1
      IOR=IOR+1
C** OPERATE RULE CARD. CHECK IF MORE THAN ALLOWED.
      IF(IOR.LE.MAXST) GO TO 950
      WRITE(6,940) MAXSTD
940 FORMAT(1H1,10X,36H# OF OPERATE RULE CARDS GREATER THAN,I4)
      STOP
950 CONTINUE
      DO 960 J=1,10
        ISTB(IOR,J,K)=IVAL(J)
960 CONTINUE
      IF(KS(1)) 860,860,970

```


PACK2890
PACK2900
PACK2910
PACK2920
PACK2930
PACK2940
PACK2950

970 WRITE(6,980) (ISTB(IOR,J,K),J=1,10)
980 FORMAT(30X,10I4)
990 GO TO 860
1000 CONTINUE
CONTINUE
RETURN
END

EVNT0010
 EVNT0020
 EVNT0030
 EVNT0040
 EVNT0050
 EVNT0060
 EVNT0070
 EVNT0080
 EVNT0090
 EVNT0100
 EVNT0110
 EVNT0120
 EVNT0130
 EVNT0140
 EVNT0150
 EVNT0160
 EVNT0170
 EVNT0180

```

SUBROUTINE EVENT
COMMON /ALPHA/DNT2,ENDPHA,ICRI,IFF,IFR,INUM,IOP1,JBB,KEQ,KKK,KZZ
1,KK1,KS1,LL,LLLAST,NEQ,NPH,NTYPE,NUM,REDAD2,REDAD1(100),RELP,RED2
2,RELPY,REPOL,STPHAS,TP,T1,XCUM,TI3,UP3,IFFEOP,TI3,TIME,TI3SUM
COMMON /N/IEQU(500),KEQU(500),ETIME(1000),XMTBF(200),XMTTR(200)

```

C C DETERMINES SMALLEST VALUE IN ETIME VECTOR
 C C

```

R=ABS(ETIME(1))
KEQ=1
DO 20 I=2,NEQ
  RR=ABS(ETIME(I))
  IF (R-RR) 20,20,10
10 R=RR
20 KEQ=I
CONTINUE
RETURN
END

```



```

SUBROUTINE TTE
COMMON /ALPHA/DNT2,ENDPHA,ICRI,IFF,IFR,INUM,IOP,T,JBB,KEQ,KKK,KZZ
1,KK1,KS1,LL,LLLAST,NEQ,NPH,NTYPE,NUM,REDAD2,REDAD1(100),RELP,RED2
2,RELPLY,REPOL,STPHAS,TP,T1,XCUM,TI3,UP3,IFFEQP,T3,TIME,T3SUM
COMMON/N/IEQU(500),KEQU(500),ETIME(1000),XMTBF(200),XMTTR(200)
COMMON/EXTRA/ KS(20),ISW(31)
COMMON/NPH/ NSS(6),IFLAG(6),TTITLE(6,31),SSTIME(6,31,2),ISS(6,31)
COMMON /TYP/EX(2,200),ISPARE(3,200),IUSED(3,200),ITT,ISEED
COMMON /DELTA/KKK2
COMMON /XXX/XXX
COMMON/VDC/VDC(50,6),IUI(200),VMTTR(200,6),TAD2
COMMON /GAMMAA/XMTBA,VAR,RELGA(100),TIMA(100),XXT(200),ITT,ISEED

10 K=KEQ
20 J=IABS(IEQU(K))
30 IF (ETIME(K)-100000.) 30,120,30
30 IF (ETIME(K)) 120,120,40

CHECK IF ANY SPARES REMAIN

IF INFINITE REPAIR TIME, NO SPARE IS USED

40 IF (ABS(XXX)-9999.) 41,120,41
41 DO 60 I=1,2
IF (ISPARE(I,J)-IUSED(I,J)) 60,60,50
50 IUSED(I,J)=IUSED(I,J)+1
IUSED(I,J)=IUSED(I,J)+1
I=I+1
GO TO 120
60 CONTINUE
IF (ISPARE(3,J)-IUSED(3,J)) 70,70,110
70 IF (ETIME(K)-100000.) 80,120,80
80 ETIME(K)=-50000.
IF (KS(12)) 340,340,90
90 WRITE (6,100) J
100 FORMAT (1X15EQUIPMENT TYPE ,I4,25H HAS CONSUMED ALL SPARES.)
GO TO 340
110 IUSED(3,J)=IUSED(3,J)+1
IUSED(3,J)=IUSED(3,J)+1
I=I+3

GENERATE TIME-TO-EVENT

120 XXX=ABS(XXX)

KKK = 0 INDICATES FIRST PHASE IN MISSION.

```

C

C
C
C
C
C

C
C
C
C
C


```

130 IF (KKK2) 140,130,140
140 IF (ETIME(K)-100000.) 160,150,160
150 ETIME(K)=-TP
160 GO TO 170
170 IF (ETIME(K)) 170,170,180
180 X=1.
190 GO TO 190
180 X=-1.
190 CALL RANDOM(ISEED,RN,1)
200 IF (II-2) 200,210,210
210 ADT=0.
220 GO TO 220
230 IF (II=II-1)
240 ADT=EX(II,J)
250 CONTINUE
260 IF (ETIME(K)) 230,230,330
270 K1=IABS(IEQU(K))
280 IF (IUI(K1)) 330,330,240
290 IU=IUI(K1)
300 ST=0.0
310 SR=1.0
320 RN3=RN
330 DO 310 I=JBB,100
340 T=XXT(2*I)
350 IF (T) 250,320,250
360 IF (ST) 300,260,300
370 T=TIME(I)+ETIME(K)
380 IF (T) 270,310,300
390 T=0
400 GO TO 310
410 LLL=XT(2*I-1)
420 XM=VDC(IU,LLL)
430 IF (XM) 280,320,280
440 R=EXP(-T/XM)
450 SR=SR*R
460 IF (SR-RN) 320,320,290
470 ST=ST+T
480 RN3=RN/SR
490 CONTINUE
500 ETIME(K)=ST-(XM*ALOG(RN3))+ABS(ETIME(K))+ADT
510 GO TO 340
520 ETIME(K)=X*(-XXX*ALOG(RN))+ABS(ETIME(K))+ADT
530 IF (IFLAG(LL)-1) 370,370,350
540 IF (ETIME(K)+500000.) 360,370,360
550 ETIME(K)=100000.
560 CONTINUE

```

```

0490 TTE
0500 TTE
0510 TTE
0520 TTE
0530 TTE
0540 TTE
0550 TTE
0560 TTE
0570 TTE
0580 TTE
0590 TTE
0600 TTE
0610 TTE
0620 TTE
0630 TTE
0640 TTE
0650 TTE
0660 TTE
0670 TTE
0680 TTE
0690 TTE
0700 TTE
0710 TTE
0720 TTE
0730 TTE
0740 TTE
0750 TTE
0760 TTE
0770 TTE
0780 TTE
0790 TTE
0800 TTE
0810 TTE
0820 TTE
0830 TTE
0840 TTE
0850 TTE
0860 TTE
0870 TTE
0880 TTE
0890 TTE
0900 TTE
0910 TTE
0920 TTE
0930 TTE
0940 TTE
0950 TTE
0960 TTE

```


RETURN
END

TTE 0979
TTE 0980


```

SUBROUTINE EVENT
COMMON /ALPHA/DNT2,ENDPHA,ICRI,IFF,IFR,INUM,IQPT,JBB,KEQ,KKK,KZZ
1,KK1,KS1,LL,LLLAST,NEQ,NPH,NTYPE,NUM,REDAD2,REDAD1(100),RELP,RED2
2,RELPLY,REPOL,STPHAS,TP,T1,XCUM,TI3,UP3,IFFEOP,TI3,TIME,T3SUM
COMMON /N/IEQU(500),KEQU(500),ETIME(1000),XMTBF(200),XMTTR(200)

C DETERMINES SMALLEST VALUE IN ETIME VECTOR
C
      R=ABS(ETIME(1))
      KEQ=1
      DO 20 I=2,NEQ
        RR=ABS(ETIME(I))
        IF (R-RR) 20,20,10
      10 R=RR
      20 KEQ=I
      CONTINUE
      RETURN
      END

```

```

EVNT00010
EVNT00020
EVNT00030
EVNT00040
EVNT00050
EVNT00060
EVNT00070
EVNT00080
EVNT00090
EVNT00100
EVNT00110
EVNT00120
EVNT00130
EVNT00140
EVNT00150
EVNT00160
EVNT00170
EVNT00180

```



```

SUBROUTINE STNDBY
COMMON /ALPHA/DNT2,ENDPHA,ICRI,IFF,IFR,INUM,IOPT,J8B,KEQ,KKK,KZZ
1,KK1,KS1,LL,LLLAST,NEQ,NPH,NTP,PE,NUM,REDAD2,REDAD1(100),RELP,RED2
2,RELPHY,REPOL,STPHAS,TP,T1,XCUM,T13,UP3,IFFECP,T3,TIME,T3SUM
COMMON /N/IEQU(500),KEQU(500),ETIME(1000),XMTBF(200),XMTTR(200)
COMMON /XXX/XXX
COMMON /STAN/ISTB(60,10,6)
DO 170 I=1,50
IF (ISTB(I,1,LL)) 10,180,10
C INDEX=1 INDICATES ALL EQUIPMENTS IN STRING ARE UP.
10 INDEX=1
DO 50 J=2,10
KK=ISTB(I,J,LL)
IF (KK) 30,60,20
20 IF (ETIME(KK)) 40,50,50
C INDEX=0 INDICATES AT LEAST ONE OF THE EQUIPMENTS IN THE STRING IS DOWN
30 KK=IABS(KK)
40 IF (ETIME(KK)) 40,40,50
40 INDEX=0
50 GO TO 60
50 CONTINUE
C K IS THE EQUIPMENT NUMBER WHICH WILL BE PUT UP OR STANDBY.
60 K=IABS(ISTB(I,1,LL))
C ISO PLUS OR MINUS INDICATES STRING OR STANDBY LOGIC.
ISO=ISTB(I,1,LL)
C IF EQUIPMENT DOWN (ETIME MINUS) LEAVE ALONE.
70 IF (ETIME(K)) 170,170,80
80 IF (ETIME(K)-100000.) 120,90,120
90 IF (INDEX) 170,110,100
100 IF (ISO) 170,170,150
110 IF (ISO) 150,170,170
120 IF (INDEX) 170,140,130
130 IF (ISO) 160,170,170
140 IF (ISO) 170,170,160
C CALL TTE TO PUT ON EQUIPMENT THAT WAS OFF(STANDBY).
150 IABC=IABS(IEQU(K))
XXX=XMTBF(IABC)
KEQ=K
CALL TTE
GO TO 170
C TO PUT OFF(STANDBY) EQUIPMENT THAT WAS ON.
160 ETIME(K)=100000.
170 CONTINUE
180 RETURN
END

```

STND00010
STND00020
STND00030
STND00040
STND00050
STND00060
STND00070
STND00080
STND00090
STND00100
STND00110
STND00120
STND00130
STND00140
STND00150
STND00160
STND00170
STND00180
STND00190
STND00200
STND00210
STND00220
STND00230
STND00240
STND00250
STND00260
STND00270
STND00280
STND00290
STND00300
STND00310
STND00320
STND00330
STND00340
STND00350
STND00360
STND00370
STND00380
STND00390
STND00400
STND00410
STND00420
STND00430
STND00440
STND00450

STAT00010
STAT00020
STAT00030
STAT00040
STAT00050
STAT00060
STAT00070
STAT00080
STAT00090
STAT01000
STAT01010
STAT01020
STAT01030
STAT01040
STAT01050
STAT01060
STAT01070
STAT01080
STAT01090
STAT02000
STAT02010
STAT02020
STAT02030
STAT02040
STAT02050
STAT02060
STAT02070
STAT02080
STAT02090
STAT03000
STAT03010
STAT03020
STAT03030
STAT03040
STAT03050
STAT03060
STAT03070
STAT03080
STAT03090
STAT04000
STAT04010
STAT04020
STAT04030
STAT04040
STAT04050
STAT04060

```

SUBROUTINE STATUS
COMMON /ALPHA/DNT2,ENDPHA,I CRI, IFF, IFR, INUM, IOPT, JBB, KEQ, KKK, KZZ
1, KKI, KSI, LL, LLLAST, NEQ, NPH, NTYPE, NUM, REDAD2, REDAD1(100), RELP, RED2
2, RELPY, REPOL, STPHAS, TP, TI, XCUM, TT3, UP3, IFFEOP, T3, TIME, T3SUM
COMMON/BETA/NRO(6,300),IB(6,300,8),NLINE(6)
COMMON/EXTRA/ KS(20),ISW(31)
COMMON/ N/IEQU(500),KEQU(500),ETIME(1000),XMTBF(200),XMTTR(200)
COMMON/NPH/ NSS(6),IFLAG(6),TITLE(6,31),SSTIME(6,31,2),ISS(6,31)

C
KID=0
NLI=NLINE(LL)
DO 130 K=1,NLI
10 KT=IB(LL,K,1)
12 KT=IB(LL,K,1)
14 IF(KID-KT)16,18,16
16 ISUM=0

C
C NRO IS NUMBER OF EQUIPMENTS REQUIRED UP
C
18 IF(NRO(LL,K))130,130,20
20 DO 60 J=2,8
30 KK=IABS(18(LL,K,J))
40 IF (KK) 70,70,40
50 IF (ETIME(KK)) 60,60,50
60 ISUM=ISUM+1
70 CONTINUE
80 IF (ISUM-NRO(LL,K)) 80,90,90
90 ETIME(KT)=-1.
100 GO TO 100
110 ETIME(KT)=1.
120 IF(KS(12))125,125,110
130 WRITE(6,120)KT,ETIME(KT)
140 FCRMAT(IX3HKK=,I5,7H ETIME=,F10.5)
150 KID=KT
160 CONTINUE
170 N=NSS(LL)+1
180 DO 160 I=1,N
190 J=ISS(LL,I)
200 IF (ETIME(J)) 140,140,150
210 ISW(I)=-1
220 GO TO 160
230 ISW(I)=1
240 CONTINUE
250 KZZ=0
260 RETURN
270 END

```



```

SUBROUTINE APPLE
DIMENSION IPRNT(50), ICHLD(50), MKBA(100)
COMMON /ALPHA/DNT2, ENDPHA, ICRI, IFF, IFR, INUM, IOPT, JBB, KEQ, KKK, KZZ
1, KKI, KSI, LL, LLLAST, NEQ, NPH, NTYPE, NUM, REDAD1(100), RELP, RED2
2, RELPY, REPOL, STPHAS, TP, TI, XNUM, TI3, UP3, IFFEOP, T3, TIME, T3SUM
COMMON /BETA/NRD(6,300), IB(6,300,8), NLINE(6)
COMMON /N/IEQU(500), KEQU(500), ETIME(1000), XMTBF(200), XMTTR(200)
COMMON /TIGAP/ UP4, XNUM, BAPRIN, AVA, XPCAP, RUNID(19), TYCOON(500)
+ , COUNTB(500), XTCUM
COMMON /RUNAP/ ITEMP2, DELT, ISSA(31), ISSC
COMMON /NPH/NSS(6), IFLAG(6), TITLE(6,31), SSTIME(6,31,2), ISS(6,31)
COMMON /PACKAP/ IBNUM( 6,500), ISYS( 6), F(200,4)

C      IF(BAPRIN)790,90,90
90 JCOUNT=0
C***** INITIALIZE
C      CLEAR STACK, NUM PRIORITY FAIL=0, SET PHASE, SET TREE PARENT TO
100 IPTR=0
L=LL
IF(ITEMP2)240,105,107
105 K=IBNUM(L,ISYS(L)-500)
GOTO 108
107 KSS=ISSA(ISSC)
108 K=IBNUM(L,ISS(L,KSS)-500)
110 KID1=IB(L,K,1)
NN=2
C***** LOOK AT CHILDREN OF PARENT
C      LOOK FROM (NN-1)TH CHILD,
120 DO 210 N=NN,8
IGRP=IB(L,K,N)
IF(IGRP)240,212,140
140 IF (ETIME(IGRP)) 150,150,210
150 IF (IGRP-500) 170,170,160
C***** WE HAVE A FAILED PRIORITY EQUIPMENT
C***** HAVE WE SEEN THIS EQ. BEFORE
170 IF (JCOUNT) 240,200,180
180 DO 190 I=1, JCOUNT
190 CONTINUE
200 CONTINUE
C***** ADD TO LIST OF FAILED PRIORITY EQ.
JCOUNT=JCOUNT+1
MKBA(JCOUNT)=IGRP
CONTINUE
210 IF(K-1)220,220,214
212 IF(K-1)220,220,214
214 IF(KID1=IB(L,K-1,1))
216 IF(KID1-KID2)220,216,220
K=K-1

```

APPL0010
 APPL0020
 APPL0030
 APPL0040
 APPL0050
 APPL0060
 APPL0070
 APPL0080
 APPL0090
 APPL0100
 APPL0110
 APPL0120
 APPL0130
 APPL0140
 APPL0150
 APPL0160
 APPL0170
 APPL0180
 APPL0190
 APPL0200
 APPL0210
 APPL0220
 APPL0230
 APPL0240
 APPL0250
 APPL0260
 APPL0270
 APPL0280
 APPL0290
 APPL0300
 APPL0310
 APPL0320
 APPL0330
 APPL0340
 APPL0350
 APPL0360
 APPL0370
 APPL0380
 APPL0390
 APPL0400
 APPL0410
 APPL0420
 APPL0430
 APPL0440
 APPL0450
 APPL0460
 APPL0470
 APPL0480


```

GOTO 108
220 IF (IPTR) 240,260,230
C***** GO BACK TO LAST PARENT
230 K=IPRNT(IPTR)
KID1=IB(L,K,1)
NN=ICHLD(IPTR)
IPTR=IPTR-1
GOTO 120
C***** LOOK AT CHILDREN OF FAILED CHILD
160 IF (N-8) 165,167,240
C ***** PUT PARENT INTO STACK AND MAKE CHILD NEXT PARENT
165 IPTR=IPTR+1
IPRNT(IPTR)=K
ICHLD(IPTR)=N+1
167 K=IBNUM(L,IGRP-500)
GOTO 108
240 WRITE (6,250)
250 FORMAT (12H APPLE ERROR)
GO TO 300
C***** BOOKKEEPING
260 IF (ITEMP2) 240,265,262
262 ISSC=ISSC-1
265 IF (ISSC) 240,265,100
FCOUNT=FLOAT(JCOUNT)
IF (ITEMP2) 270,270,280
C ***** SUMMING DOWNTIME BY EQ
270 DO 275 I=1, JCOUNT
275 TYCOON(MKBA(I))=TYCOON(MKBA(I))+DELT/FCOUNT
GOTO 300
C ***** SUMMING ABORTS BY EQ.
280 DO 290 I=1, JCOUNT
290 COUNTB(MKBA(I))=COUNTB(MKBA(I))+1/FCOUNT
300 CONTINUE
RETURN
C BEGINNING OF FINAL PRINTOUT
C
790 CONTINUE
WRITE (6,800) (RUNID(I),I=1,19)
800 FORMAT(1H1,3X,19A4//)
WRITE (6,810)
810 FORMAT(32X,19HCRITICAL EQUIPMENTS//32X,18HUNAVAILABILITY AND/
1X25HPERCENT OF UNAVAILABILITY//)
WRITE (6,820)
820 FORMAT (24X4HNAME,17X7HNUM HRS,11X5HUNAVA,2X7HPERCENT,6X8HEQU TYPEAPPL0920
1,5X7HEQU NUM/)
C
C SKIPS BAD APPLE PRINTOUT WHEN AVA OR REL = 1.0

```



```

C
830 IF (AVA-1.) 830,880,830
    TR=TYCOON(1)
    INDEX=1
    DO 850 I=2,NEQ
    TRR=TYCOON(I)
    IF (TR-TRR) 840,850,850
840 TR=TRR
    INDEX=I
850 CONTINUE
    TYCUM=TYCOON(INDEX)/TT3
    TYCUM2=TYCOON(INDEX)/(TT3-UP4)*100.
    IF (TYCOON(INDEX)) 860,880,860
860 IXX=IABS(IEQU(INDEX))
    WRITE (6,870) (F{IXX,J},J=1,4),TYCOON(INDEX),TYCUM,TYCUM2,IXX
    1,INDEX
870 FORMAT (20X4A4,F20.4,4XF8.4,F8.2,8XI4,10XI4)
    TYCOON(INDEX)=0.0
    GO TO 830
880 WRITE (6,800) (RUNID(I),I=1,19)
910 FORMAT(32X,19HCRTICAL EQUIPMENTS//32X,17HUNRELIABILITY AND/
    127HPERCENT OF MISSION FAILURES//)
    WRITE (6,920)
920 FORMAT (12X11HDESCRIPTION,8X3HNO.,6X6HUNREL ,3X7HPERCENT,2X13HEQUI
    1P EQUIP /28X8HFAILURES,22X10HTYPE NO.)
    IF (XPCAP-1.) 930,1090,930
C*****THROW OUT EQUIPMENTS WITH ZERO FAILURES
C
930 INEWA=0
    DO 950 I=1,NEQ
    IF (COUNTB(I)) 950,950,940
940 INEWA=INEWA+1
    MKBA(INEWA)=I
950 CONTINUE
C*****RANK LIST BY NO. FAILURES
C
    TOTAL=XNUM-XTCUM
955 IF (INEWA-1) 1010,975,952
952 INDEX=MKBA(1)
    NN=1
    TR=COUNTB(INDEX)
    DO 970 I=2,INEWA
    IF (TR-COUNTB(MKBA(I))) 960,970,970
960 INDEX=MKBA(I)
    NN=I

```



```

970 TR=COUNTB(IINDEX)
977 CONTINUE
    UNREL=TR/XNUM
    PERC=TR/TOTAL*100.
    IND=IABS(IEQU(IINDEX))
    WRITE(6,990) (F(IND,J),J=1,4),TR,UNREL,PERC,IND,INDEX
990 FORMAT (9X4A4,3XF6.1,5XF6.4,3XF6.2,4X14,3X14)
    MKBA(NN)=MKBA(INEWA)
    INEWA=INEWA-1
    GOTO 955
975 IINDEX=MKBA(1)
    TR=COUNTB(IINDEX)
    GOTO 977
1010 JNUM=IFIX(XNUM)
    WRITE (6,1020) JNUM
1020 FORMAT (//9X19HTOTAL NO. MISSIONS=,I4)
    ITOTAL=TOTAL
    WRITE (6,1030) ITOTAL
1030 FORMAT (9X27HTOTAL NO. MISSION FAILURES=,I4)
1090 RETURN
    END

```

```

APPL1450
APPL1460
APPL1470
APPL1480
APPL1490
APPL1500
APPL1510
APPL1520
APPL1530
APPL1540
APPL1550
APPL1560
APPL1570
APPL1580
APPL1590
APPL1600
APPL1610
APPL1620
APPL1630
APPL1640
APPL1650

```



```

SUBROUTINE SPARES
  FLSIP COSAL MODEL WITH INSURANCE CUT POINT READ IN WITH DATA
  COMMON /ALPHA/DNT2,ENDPHA,ICRI,IFF,IFR,INUM,IOPT,JBB,KEQ,KKK,KZZ
  1,KK1,KS1,LL,LLLAST,NEQ,NPH,NTYPE,NUM,REDAD2,REDAD1(100),REL,RED2
  2,REL,REPOL,STPHAS,TP,T1,XCUM,T13,UP3,IFFEOP,T3,TIME,T3SUM
  COMMON /N/IEQU(500),KEQU(500),ETIME(1000),XMTBF(200)
  COMMON /TYP/EX(2,200),ISPARE(3,200),IUSED(3,200)
  COMMON /CSPARE/ SPRI1,SPR2,SPR3,SPR4,SPR5,SPR6,SPR7,SPR8,SPR9
  1,SPR10,SPR11,SPR12,SPR13,SPR14,ITMPOP(200)
  CUT=SPRI1
  DO 10 I=1,NTYPE
    ITMPOP(I)=0
  10 CONTINUE
  DO 20 I=1,NEQ
    ITMPOP(IEQU(I))=ITMPOP(IEQU(I))+1
  20 CONTINUE
  DO 90 I=1,NTYPE
    EX90DD=((8766./XMTBF(I))/4.)*ITMPOP(I)
    IF(EX90DD-1.) 60,30,30
  90 CONTINUE
  DEMAND BASED ITEM
  30 PRBSUM=EXP(-EX90DD)
  DUM=PRBSUM
  KFACT=1
  K=0
  40 K=K+1
  KFACT=KFACT*K
  PRBSUM=PRBSUM+DUM*(EX90DD**K)/KFACT
  IF(PRBSUM-.9) 40,50,50
  50 ISPARE(I,I)=K
  GO TO 90
  60 IF(4.*EX90DD-CUT) 80,80,70
  INSURANCE ITEM
  70 ISPARE(I,I)=1
  GO TO 90
  80 ISPARE(I,I)=0
  90 CONTINUE
  DO 100 I=1,NTYPE
    DO 100 J=2,3
      ISPARE(J,I)=0
  100 CONTINUE
  RETURN
  END

```


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